Northern Harrier (*Circus cyaneus*): A Technical Conservation Assessment

Prepared for the USDA Forest Service,
Rocky Mountain Region,
Species Conservation Project

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Gary L. Slater
Christine Rock
Ecostudies Institute
P.O. Box 703
Mount Vernon, WA 98273

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AUTHORS' BIOGRAPHIES

Gary L. Slater is the Research Director for Ecostudies Institute, Mount Vernon, Washington. He received a M.S. degree in 1997 in Wildlife Ecology from the University of Florida where he investigated the breeding ecology and nest-site selection of brown-headed nuthatches and eastern bluebirds in southern Florida. He received a B.S. in Wildlife Science in 1989 from Purdue University. His current research focuses on the population ecology of reintroduced cavity-nesting species in Everglades National Park and long-term monitoring of pineland avifauna in national parks in southern Florida. In Washington State, he is investigating the stopover ecology of waterfowl and shorebirds using estuarine habitats and adjacent agricultural lands.

Christine Rock is a wildlife biologist for Ecostudies Institute. She received her B.Sc. Honors Zoology Degree in 2003 from The University of Western Ontario. She is currently completing a position at the Canadian Wildlife Service and Environment Canada where she is studying land use impacts and effects of habitat loss on plant and bird community composition, diversity, and structure in the south Okanogan, British Columbia.

COVER PHOTO CREDIT

Northern harrier (*Circus cyaneus*). Photograph by Thomas O'Neil, used with permission.

Summary of Key Components for Conservation of the Norther Harrier

The northern harrier (*Circus cyaneus*) is considered globally "secure" by the Natural Heritage Program because of its wide distribution across North America. However, because of its low density and often nomadic behavior, assessing this species' population status and evaluating trend data are difficult, even with large-scale and long-term monitoring programs such as the Breeding Bird Survey. Nevertheless, historic and recent evidence suggest that the number of breeding harriers has declined across the species' range. USDA Forest Service Region 2 represents a segment of the core of this species' breeding range, and Breeding Bird Survey data suggest that northern harrier populations in Region 2 states have exhibited long-term declines that substantially exceed national trends.

Breeding northern harriers require large tracts (greater than 100 ha) of habitat. The greatest threats to northern harriers in Region 2 are loss of wetland and grassland habitats, and the effects of habitat fragmentation, primarily from agricultural production. Northern harriers nest and hunt in moderate to tall vegetation with dense litter cover. Agricultural activities that remove vegetation, such as grazing and mowing, can make habitat unsuitable or lower habitat quality, as well as destroy active nests. Habitat fragmentation also may reduce recruitment by causing higher nest predation rates and increased competition with other predators for their primary prey items.

The U.S. Fish and Wildlife Service lists the northern harrier as a species of special concern, and it is listed as a priority species in the Colorado and Wyoming Partners in Flight bird conservation plans. Yet, conservation programs for this species have not been developed, in part, because little data are available on the effects of management practices on demographics. Conservation in Region 2 should focus on maintaining large blocks of habitat with moderate to tall vegetation and dense litter cover. Federal grasslands can play a significant role in the conservation of this species by serving as demonstration sites and promoting management activities that maintain their land's biotic integrity. Still, less than 7 percent of the grasslands within Region 2 states are in federal ownership, and management of these lands alone is unlikely to ensure long-term, regional population viability of this species. There is a critical need to develop incentive-based partnerships between private landowners, conservation organizations, and state and federal agencies aimed at the conservation of Great Plains wildlife and the habitats upon which they depend.

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INTRODUCTION

This conservation assessment is one of many being produced to support the Species Conservation Project for the Rocky Mountain Region (Region 2) of the USDA Forest Service (USFS). The northern harrier (*Circus cyaneus*) is the focus of an assessment because it is listed as a sensitive species by Region 2 (**Figure 1**). Within the National Forest System, a sensitive species is a plant or animal whose population viability is identified as a concern by a Regional Forester because of significant current or predicted downward trends in abundance or habitat capability that would reduce its distribution [FSM 2670.5 (19)]. Because a sensitive species may require special management, knowledge of its biology and ecology is critical. This assessment addresses the biology and ecology of the northern harrier throughout its range in Region 2. This introduction defines the goals of the assessment, outlines its scope, and describes the process used in its production.

Goal

Species conservation assessments produced as part of the Species Conservation Project are designed to provide land managers, biologists, government agencies, and the public with a thorough discussion of the biology, ecology, conservation, and management of select species based on current scientific knowledge. The assessment goals limit the scope of the work to critical summaries of scientific knowledge, discussion of implications of that knowledge, and outlines of information needs. This assessment does not seek to develop prescriptive management recommendations. Rather, it provides the ecological background upon which management must be based and focuses on the consequences of changes in the environment that result from management (i.e., management implications). This assessment does cite management recommendations proposed elsewhere, however, and when management recommendations have been implemented, we describe the results of the implementation.

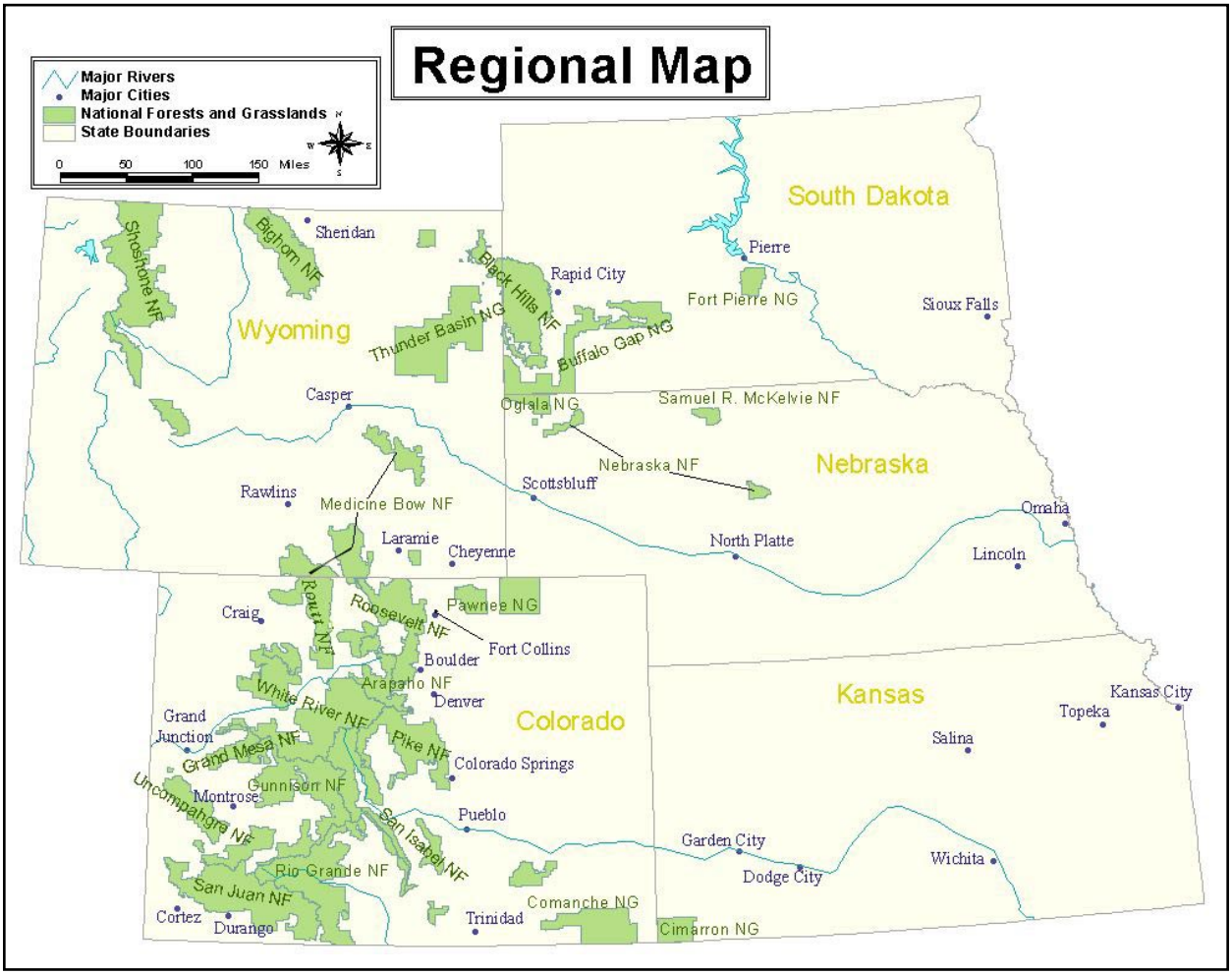

Figure 1. Map of USDA Forest Service Region 2. National grasslands and forests are shaded in green.

Scope

The northern harrier conservation assessment examines the biology, ecology, conservation, and management of this species with specific reference to the geographic and ecological characteristics of the USFS Rocky Mountain Region. Although some of the literature on the species originates from field investigation outside of Region 2, this document works to place that literature in the ecological and social context of the central and southern Rockies. Similarly, this assessment is concerned with characteristics of the northern harrier in the context of the current environment rather than under historical conditions. The evolutionary environment of the species is considered in conducting the synthesis, but placed in a current context.

In producing the assessment, we reviewed refereed literature, non-refereed publications, research reports, and data accumulated by resource management agencies. Not all publications on northern harrier are referenced in the assessment, nor were all published materials considered equally reliable. The assessment emphasizes refereed literature because this is the accepted standard in science. Non-refereed publications or reports were used when published information was not available, but these were regarded with greater uncertainty.

Treatment of Uncertainty

Science represents a rigorous, systematic approach to obtaining knowledge. Competing ideas regarding how the world works are measured against observations. However, because our descriptions of the world are always incomplete and observations limited, science focuses on approaches for dealing with uncertainty. Sorting among alternatives may be accomplished using a variety of scientific tools (experiments, modeling, logical inference). In this assessment, the strength of evidence for particular ideas is noted, and alternative explanations are described when appropriate. While well-executed experiments represent a strong approach to developing knowledge, alternative approaches such as modeling, critical assessment of observations, and inference are accepted as sound approaches to understanding and used in synthesis for this assessment.

Publication of Assessment on the World Wide Web

To facilitate use of species conservation assessments, they are being published on the Region 2 World Wide Web site. Placing the documents on the Web makes them available to agency biologists and managers, and the public more rapidly than publishing them as reports. Moreover, it facilitates their revision, which will be accomplished based on guidelines established by Region 2.

Peer Review

Conservation assessments developed for the Species Conservation Project have been peer reviewed prior to their release on the Web. This report was reviewed through a process administered by the Society for Conservation Biology, employing at least two recognized experts on this or related taxa. Peer review was designed to improve the quality of communication and to increase the rigor of the assessment.

MANAGEMENT STATUS AND NATURAL HISTORY

Management Status

Within the United States, the northern harrier is designated a Bird of Conservation Concern by the U.S. Fish and Wildlife Service (2002). It is also listed as a Bird of Conservation Concern in Region 6 of the U.S. Fish and Wildlife Service, which includes all of the states within USFS Region 2, and in many Bird Conservation Regions (BCR) (i.e., Central Mixed-grass [BCR 19], Shortgrass Prairie [BCR 18], Southern Rockies/Colorado Plateau [BCR 16], and Prairie Pothole [BCR 11]). USFS Region 2 listed the northern harrier in its revised sensitive species list, effective December 1, 2003. No state wildlife agencies within Region 2 have a special designation for the northern harrier.

The Natural Heritage Program's global rank for the northern harrier is G5, "secure" (NatureServe Explorer 2004). Within the states of Region 2, heritage program ranks for breeding or resident populations vary from S2 (imperiled) in parts of Kansas to S5 (secure) in parts of Wyoming (**Table 1**) .

The northern harrier is listed as a priority bird species in wetland habitats in both the Wyoming and Colorado Partners in Flight (PIF) bird conservation plans (Colorado Partners in Flight 2000, Nicholoff 2003). In Wyoming, the northern harrier is considered a Level III priority species, indicating that conservation actions may be recommended based on local interest. In Colorado, the northern harrier is listed as a priority bird species in the Central Shortgrass Prairie and the Colorado Plateau Physiographic Areas. State PIF bird

Table 1. Status of the northern harrier in states within USDA Forest Service Region 2 based on the Natural Heritage Program rankings (NatureServe Explorer 2004).

State	Natural Heritage Rank
Wyoming	S4B and S5N
South Dakota	S5B
Nebraska	S3
Kansas	S2B and S4N
Colorado	S3B

S2 Imperiled – Vulnerable to extirpation, rarity due to restricted range, few populations, or steep declines.

S3 Vulnerable - Either because rare and uncommon, or found only in a restricted range (even if abundant at some locations).

S4 Apparently Secure - Uncommon but not rare, and usually widespread, although the species may be quite rare in parts of its range, especially at the periphery.

S5 Secure - Common, widespread, and abundant; essentially ineradicable under present conditions.

B Breeding population.

N Nonbreeding population.

conservation plans for South Dakota, Nebraska, and Kansas have not been completed or published.

Existing Regulatory Mechanisms, Management Plans, and Conservation Strategies

No regulatory mechanisms or laws specifically target protection of the northern harrier. However, several laws exist that provide protection to a broad array of wildlife species including the northern harrier. The Migratory Bird Treaty Act of 1918 establishes a federal prohibition, unless otherwise permitted by regulations, to "pursue, hunt, take, capture, kill, attempt to take, possess, offer for sale, sell, offer to purchase, purchase, export, at any time, or in any manner, any migratory bird, including any part, nest, or egg of any such bird" (16 U.S.C. 703). The National Environmental Policy Act of 1969 requires that federal agencies specify environmentally preferable alternatives in land use management planning. Under the National Forest Management Act of 1976, the USFS is required to sustain habitats that support healthy populations of all native and desired non-native plant and animal species on national forests and grasslands. Additional laws with which USFS management plans must comply are the Endangered Species, Clean Water, Clean Air, Mineral Leasing, Federal Onshore Oil and Gas Leasing Reform, and Mining and Minerals Policy acts; all are potentially relevant to northern harrier conservation.

Although existing laws appear adequate to protect northern harrier breeding habitat on federal lands in Region 2, protection solely of these lands is unlikely to result in conservation of this species. The amount of federally protected wetland and grassland habitats upon which harriers depend is small relative to the overall area of land within Region 2. Conservation of this species will depend not only on protection of federal lands, but also on conservation efforts by private landowners, state wildlife agencies, and private conservation groups.

Specific management plans and conservation strategies for the northern harrier in USFS Region 2 have not been developed. However, within the Wyoming and Colorado PIF bird conservation plans, key management recommendations are provided for the northern harrier due to their recognition as priority species. Both documents identify important conservation recommendations:

- identify and protect larger wetlands (greater than 100 ha) used by this species
- maintain a mosaic of grassland and wetland habitats in varied successional stages to ensure that some breeding habitat is always available
- minimize grazing in wet meadows and pastures to maintain nesting cover
- maintain habitat for small mammal populations such as abandoned fields and other habitats with dense grasses and cover
- delay agricultural practices such as haying until nesting is complete, or avoid the area immediately around harrier nests (Colorado Partners in Flight 2000, Nicholoff 2003).

Biology and Ecology

Systematics and species description

The northern harrier is in the Order: Falconiformes, Family: Accipitridae, and it is represented by only one North America subspecies, *Circus cyaneus hudsonius* (American Ornithologists' Union 1998). A second subspecies, the hen harrier (*C. c. cyaneus*), breeds in Europe and Asia, and winters in North Africa and Asia (Wheeler 2003). According to Simmons (2000), however, the two subspecies deserve specific status based on long-term isolation and slight genetic differences.

The northern harrier is a slender, medium-sized raptor with long wings and a long tail, and slender legs (MacWhirter and Bildstein 1996). The northern harrier is distinguished from other raptors by its low, coursing flight, and its distinctive, narrow wings, slim tail, and white rump patch (MacWhirter and Bildstein 1996). Well-defined auricular disks and facial ruff give northern harriers an owl-like appearance. Functionally, these features contribute to the northern harrier's well-developed auditory ability (MacWhirter and Bildstein 1996, Carter 1998).

Adults are sexually dimorphic with respect to plumage and size. The adult male has a pale gray dorsal surface, black-tipped wings, and a speckled brown and white under part (Bildstein 1988). The average weight of an adult male is 367.4 g with a body length of 44 to 51 cm and a wingspread of 102 to 114 cm (Hamerstrom 1986, Bildstein 1988). In contrast, the adult female is dark brown above and russet with some streaking below, weighs approximately 529.9 g and has a 110 to 137 cm wingspan (Hamerstrom 1986, Bildstein 1988, MacWhirter and Bildstein 1996). Both male and female juveniles have a cinnamon-colored breast with a darker brown back and wings and retain their immature plumage throughout the first winter and into the succeeding spring. Consequently, they can be difficult to differentiate from adult females in spring and early summer (Bent 1961, Bildstein 1988). In all plumages, a white rump patch is present.

Distribution and abundance

The northern harrier has a global breeding distribution that includes North America, Europe, and Asia. The North American subspecies has a large breeding range, but it is locally confined to open wetland and upland habitats (MacWhirter and Bildstein 1996). It breeds from northern Alaska and Canada, south to northern Baja California, and east to southern Texas, southern Missouri, central West Virginia, and southeastern Virginia (**Figure 2**, **Figure 3**; NatureServe Explorer 2004).

According to Breeding Bird Survey (BBS) data, breeding density varies across North America, with some of the highest numbers in the provinces (Alberta, Saskatchewan, Manitoba) and states (Montana, North Dakota, and South Dakota) of the northern Great Plains (**Figure 3**; Sauer et al. 2003). Within the northern harrier's range, abundance varies with respect to habitat, with the highest abundance of breeding birds in wet grasslands and marshes (MacWhirter and Bildstein 1996). Intermediate breeding densities are found in dry grasslands, and low densities in shrub-steppes and desert habitats (MacWhirter and Bildstein 1996). The northern harrier is moderately nomadic, and local abundance varies annually in response to prey abundance (Hamerstrom 1979, Grant et al. 1991), the incidence of polygyny within mating systems (Balfour and Cadbury 1979, Simmons et al. 1986a,b), nest site fidelity (Sealy 1967, Balfour and Cadbury 1979), and habitat quality (Simmons and Smith 1985).

During the non-breeding season, the northern harrier winters from southern Canada and the northern contiguous United States, south through the United Sates and into Mexico (**Figure 4**). Based on Christmas Bird Count (CBC) data, Johnsgard (1990) estimated the wintering northern harrier population in Canada and the United States to be 111,500; presumably the breeding population exceeds this number because an unknown number of birds winter in the Caribbean Islands and Central America. The densest wintering populations occur in the southern Great Plains and Great Basin region (**Figure 4**; Root 1988, Sauer et al. 1996).

Regional distribution and abundance

Colorado: Northern harriers reside throughout most of Colorado but are usually more abundant during migration than during the breeding season (Andrews and Righter 1992; See **Figure 5** for map of potential harrier habitat) They are found in an array of open habitats, but generally avoid high elevations in the Rocky Mountains and dry areas in the southeast (Carter 1998). Fifty-seven percent of northern harriers detected on the breeding bird atlas survey were found on the eastern Plains, with most located in the northern half (Carter 1998). Wintering northern harriers are uncommon to fairly commonly in the western valleys,

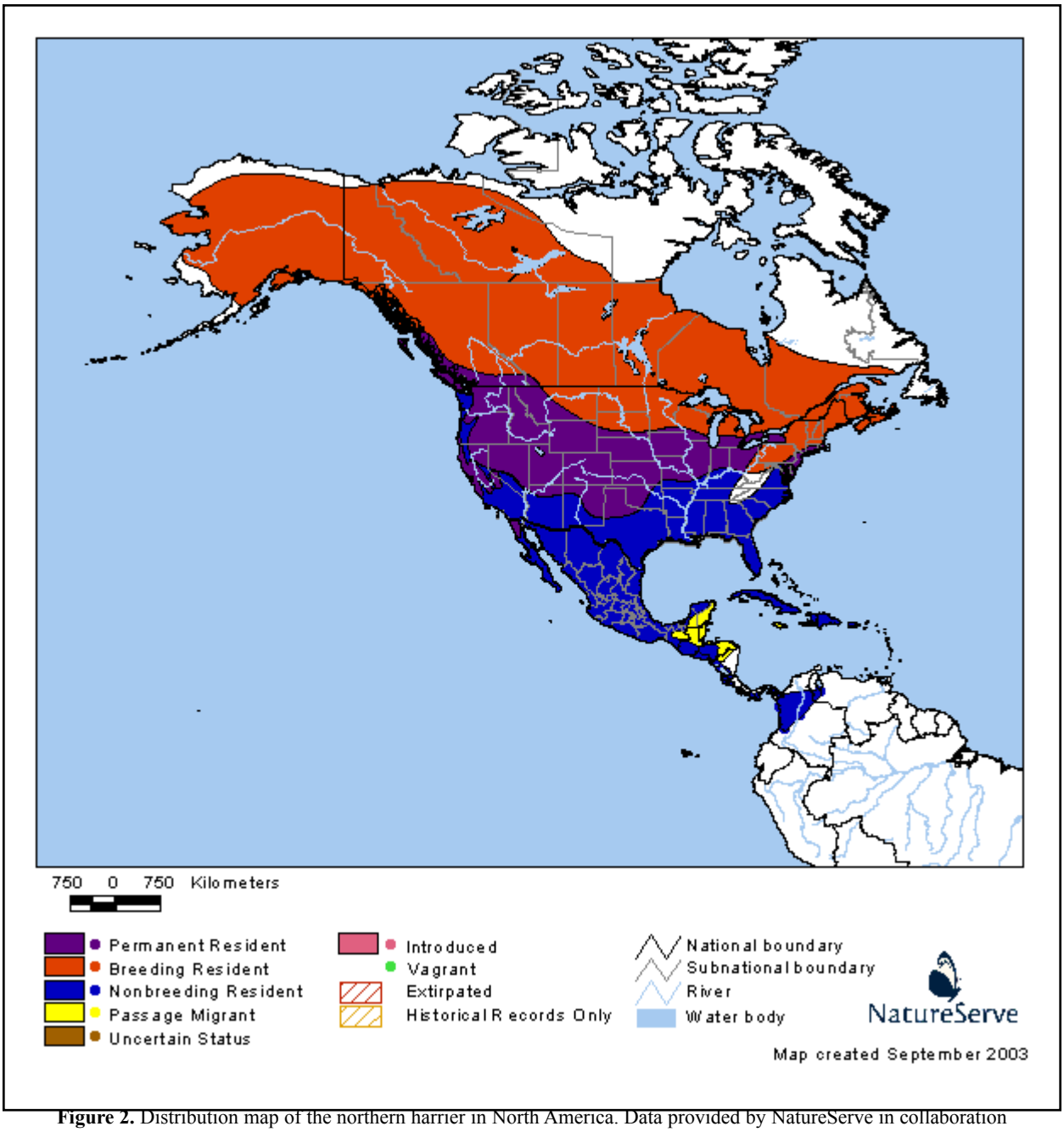

Figure 2. Distribution map of the northern harrier in North America. Data provided by NatureServe in collaboration with Robert Ridgely, James Zook, The Nature Conservancy - Migratory Bird Program, Conservation International - CABS, World Wildlife Fund - US, and Environment Canada – WILDSPACE (Ridgely et al. 2003).

San Luis Valley, eastern plains, and southern Colorado near Monte Vista and Alamosa (Root 1988, Andrews and Righter 1992).

Nebraska: During the breeding season northern harriers are uncommon in Nebraska, with breeding concentrated in the Sandhills region and in northern Garden, southern Sheridan, and Cherry counties, where marshlands remain (Sharpe et al. 2001). The northern harrier is found statewide during most winters, but it may be absent when winter conditions are harsh (Sharpe et al. 2001). The northern harrier is most numerous during spring and fall migration (Sharpe et al. 2001). Spring migration sightings are high along the Missouri Valley, which may serve as a north-south migration corridor. During fall migrations, northern harrier counts were high at Lake McConaughy and in the western Panhandle area (Sharpe et al. 2001).

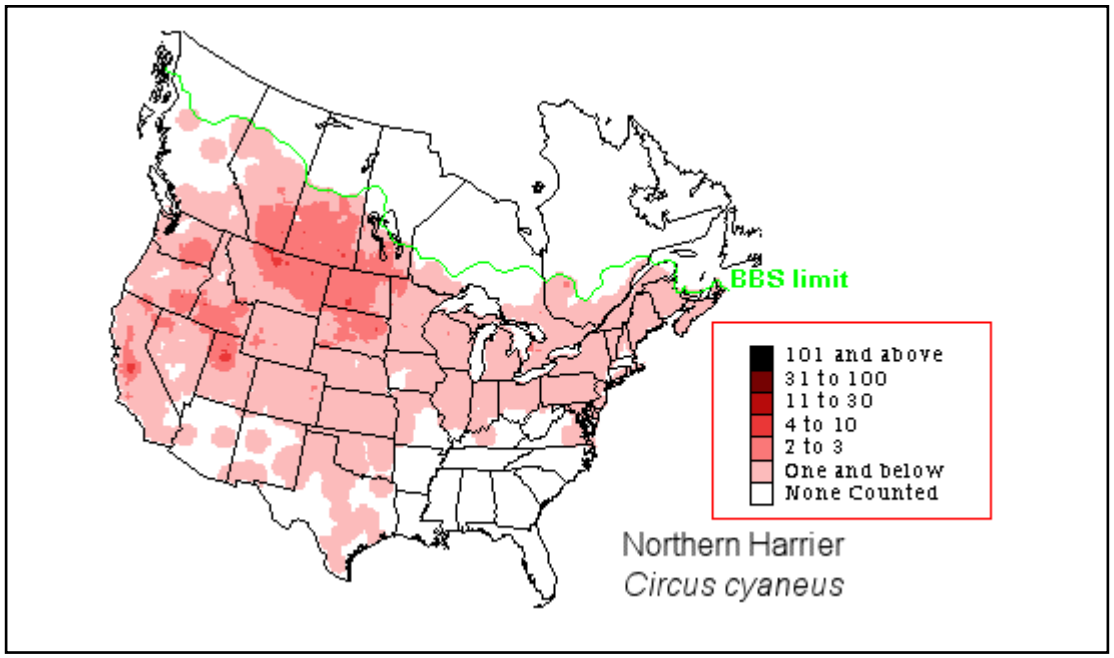

Figure 3. Relative breeding season abundance (average number of birds/route) of the northern harrier based on Breeding Bird Survey data, estimated over the interval from 1982 to 1996 (Sauer et al. 2003).

Wyoming and South Dakota: During the breeding season, the northern harrier is common and widespread throughout Wyoming (See **Figure 6** for map of predicted available habitat) and South Dakota (**Figure 7**). It is, however, relatively absent from the Black Hills region (Johnsgard 1979). During the nonbreeding season, the northern harrier is absent or rare in Wyoming and the Dakotas (MacWhirter and Bildstein 1996).

Kansas: Few northern harriers breed in Kansas (Busby and Zimmerman 2001). BBS data suggest that northern harriers are more abundant in the High Plain physiographic region of western Kansas and the Arkansas Lowland, and less abundant in eastern Kansas (Busby and Zimmerman 2001). Nests that have been observed during the breeding season are in watersheds in the Konza Prairie region of northeastern Kansas and in Conservation Reserve Program (CRP) fields in southwestern Kansas (Busby and Zimmerman 2001).

Regional discontinuities in distribution and abundance

Northern harriers are relatively widespread throughout Region 2. However, their distribution and abundance are discontinuous, reflecting their habitat requirements, their nomadic lifestyle, and fluctuations in their prey (Simmons and Smith 1985). The loss of wetland and grassland habitats has exacerbated the fragmentation of their populations (MacWhirter and Bildstein 1996). The existence of patchy populations suggests localized subpopulations. However, there is little information available on northern harrier movements between populations or the genetic and demographic consequences of this pattern.

Population trend

The most notable long-term effort to assess broad scale patterns and population trends in birds (including the northern harrier) is the BBS, conducted annually in Canada and the United States since 1966. The BBS produces an index of relative abundance rather than a measure of absolute abundance or density estimate for breeding bird populations. Data analyses assume that fluctuations of abundance indices are representative of the population as a whole. However, these data should be viewed with caution, because large sample sizes are required to average local variations and to reduce the effects of sampling error (variation in counts attributable to both sampling technique and real variation in trends; Sauer et al. 2003). Consequently, local, or even regional trends, if based on few surveys, are difficult to interpret and can be quite different from larger-scale BBS trends (Peterjohn and Sauer 1999).

Northern harriers are often nomadic and occur at low density; thus population trends are not robustly captured by BBS monitoring (**Figure 8**). Credibility

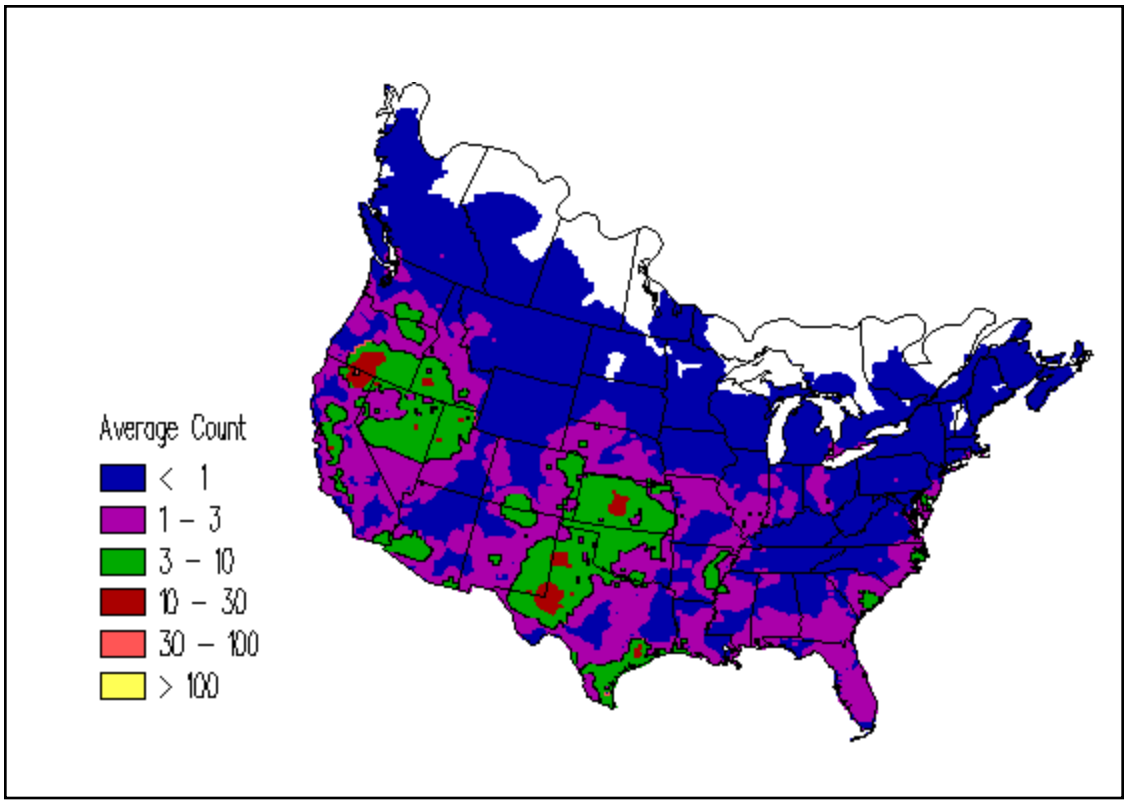

Figure 4. Winter season distribution and relative abundance based on Christmas Bird Counts of northern harriers, estimated over the interval from 1982 to 1996 (Sauer et al. 1996).

measures have been developed to assess the validity of BBS data (Sauer et al. 2003). With the exception of data presented from South Dakota (which is from the highest reliability category with moderate precision and moderate abundance on routes), all other BBS results for the harrier, including range-wide data, are categorized as having deficiencies. Deficiencies include one or more of the following sampling errors:

- ❖ low abundance; regional abundance is less than 1.0 birds per route
- ❖ small sample size; sample is based on less than 14 routes for the long term
- ❖ imprecision; results are so imprecise that a 3 percent change per year would not be detected over long-term periods
- ❖ inconsistent; sub-interval trends are significantly different from each other (Sauer et al. 2003).

According to the BBS (Reference Period 1966 - 2003), northern harrier populations have declined at a non-significant annual rate of 0.6 percent in the United States (**Table 2**, **Figure 8**; Sauer et al. 2003). The average number of northern harrier detections per route (i.e., 50 points; n = 736) in the United States was 0.46. Within Region 6 of the U.S. Fish and Wildlife Service (Montana, North and South Dakota, Wyoming, Nebraska, Utah, Colorado, and Kansas), northern harriers have declined, again non-significantly, at a rate of 1.1 percent per year (**Table 2**; Sauer et al. 2003).

The National Audubon Society's CBC represents another long-term effort to assess population trends of bird populations through monitoring during the nonbreeding season. Like the BBS, there are significant limitations in the CBC's ability to investigate population trends, and data from CBC data need to be viewed with caution (Sauer et al. 1996). During the period from 1952 to 1971, CBC data for the conterminous United States indicate a 41 percent population decline (Brown 1973). However, a more recent analysis by Sauer et al. (1996) for an extended survey period (1959 to 1988) indicates a survey-wide trend of -0.4 percent per year in the United States (n = 1712 survey circles).

Migration count stations are a methodological alternative to evaluate regional population trends for raptor species that occur at low densities and whose

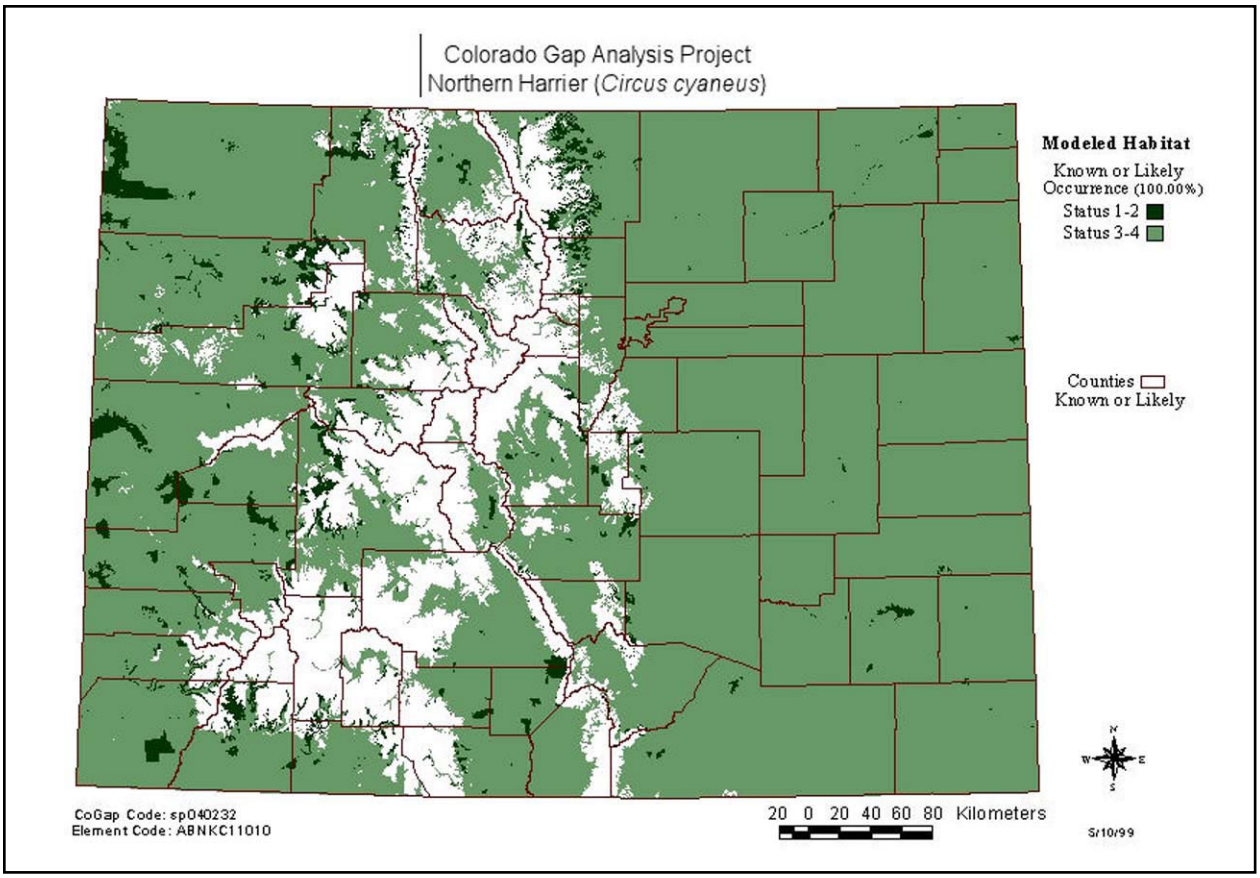

Figure 5. Modeled potential habitat for the northern harrier in Colorado created by Colorado Gap Analysis Project.

populations are not well monitored by existing national programs. The validity of migration counts has been questioned due to issues such as weather influences and poor standardization of count procedures, locations, the number of observers, and observer proficiency (Dunn and Hussell 1995, Lewis and Gould 2000). However, with the combination of more standardized data collection methods, more rigorous statistical methodology, and increasing evidence that migration counts reflect actual population trends, the value of migration count stations as a monitoring tool has increased (Hoffman and Smith 2003). Migration count stations are not well established in Region 2, but HawkWatch International coordinates a series of sites in the nearby Intermountain and Rocky Mountain flyways of North America. A study of site-specific trends in annual passage rates (raptors per 100 hours of observation) from six sites in Nevada, Utah, Montana, Arizona, and New Mexico using 10 to 19 year datasets (1977 – 2001) found variable population trends (Hoffman and Smith 2003). In Nevada, counts indicated significant long-term increases for northern harriers while trends from the remaining five sites were stable (Hoffman and Smith 2003).

Regional

Within some states in Region 2, BBS data indicate substantially larger declines than rangewide trends (**Figure 8**). For example in South Dakota, which is the only state in Region 2 with robust data, northern harriers have declined during the period from 1966 to 2003 at a rate of 4.1 percent per year; the average number of detections per route was 1.20 (**Table 2**). Although not statistically significant, this translates to a 66 percent decline in population size over the 27 years in which the BBS was conducted. Similarly, harriers have declined by 4.8 percent (0.21 birds per route) and 7.2 percent per year (0.37 birds per route) in Nebraska and Kansas, respectively. In Colorado, harrier populations have declined at an annual rate of 1.7 percent (0.34 birds per route). Only in Wyoming have harriers increased (0.1 percent per year; 0.49 birds per route).

Although the BBS trend data must be viewed cautiously, the significant loss and degradation of wetland and grassland habitats within Region 2 prior to BBS data in 1966 support the hypothesis of substantial

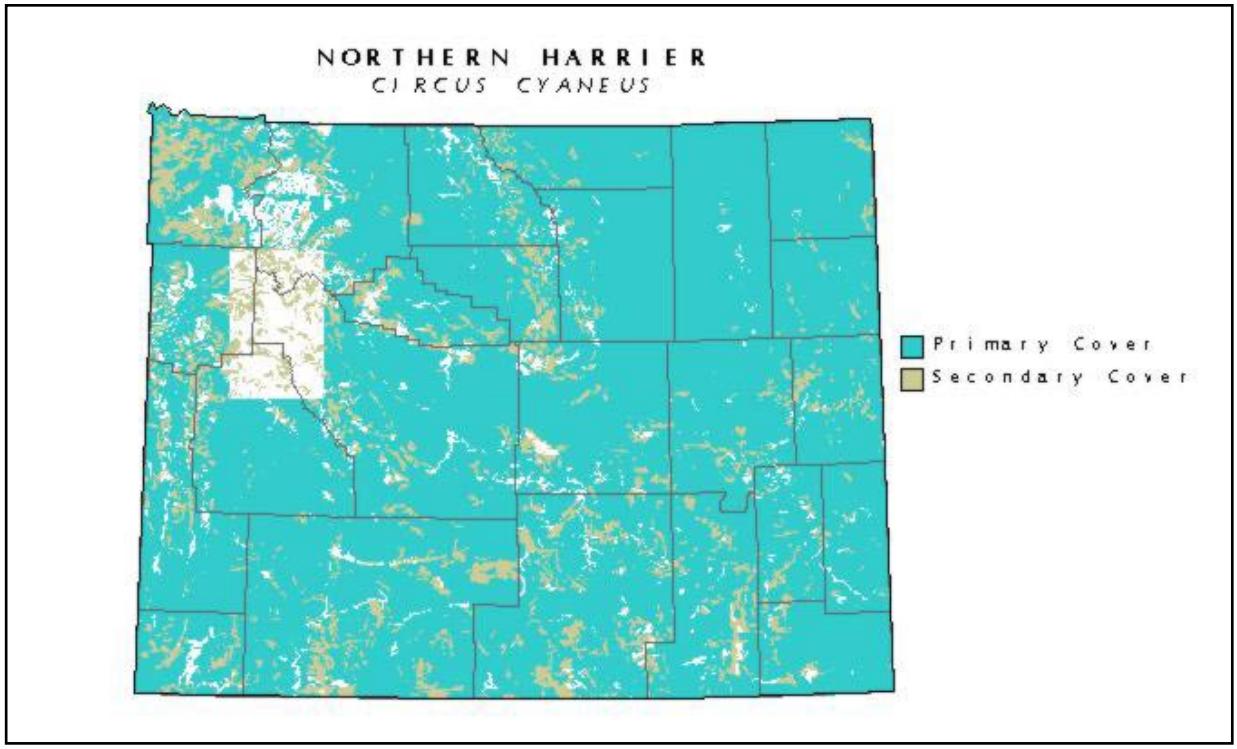

Figure 6. Map of predicted occurrences for the northern harrier in Wyoming based on GAP Analysis (Fertig and Beauvais 1999).

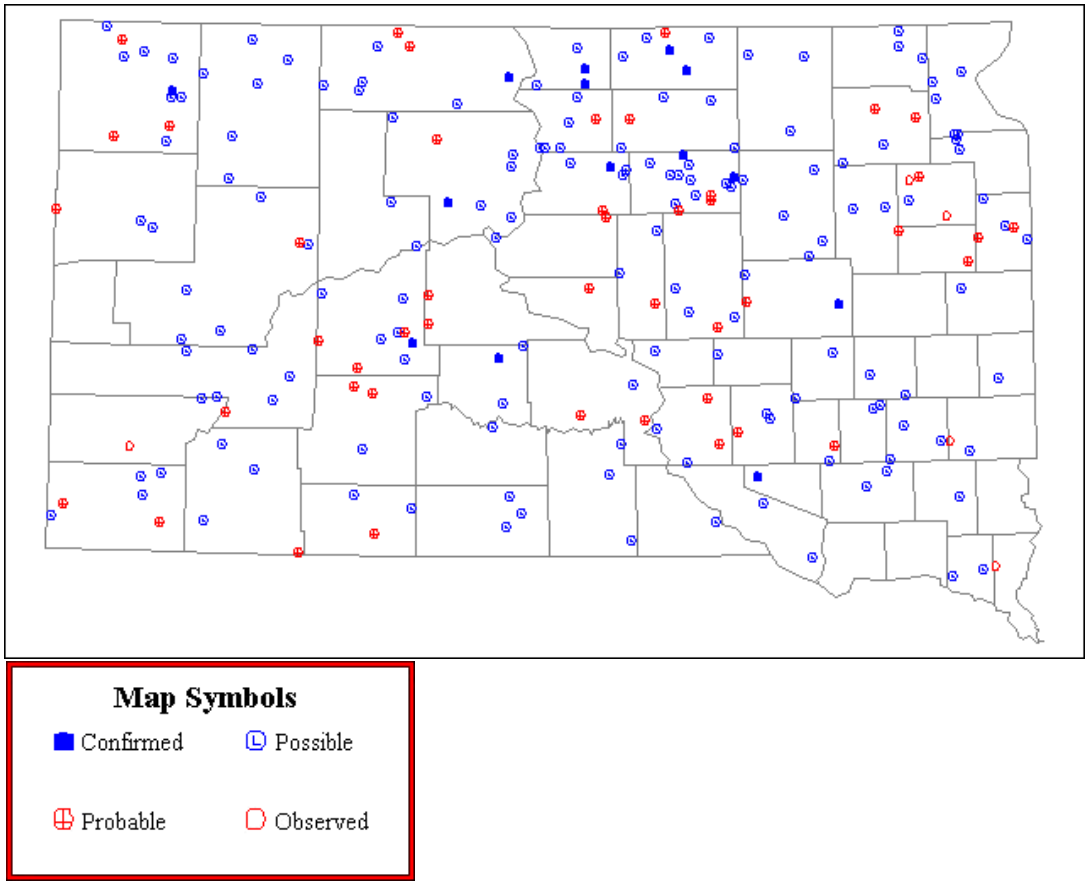

Figure 7. Map of South Dakota Breeding Bird Atlas northern harrier detections (Peterson 1995).

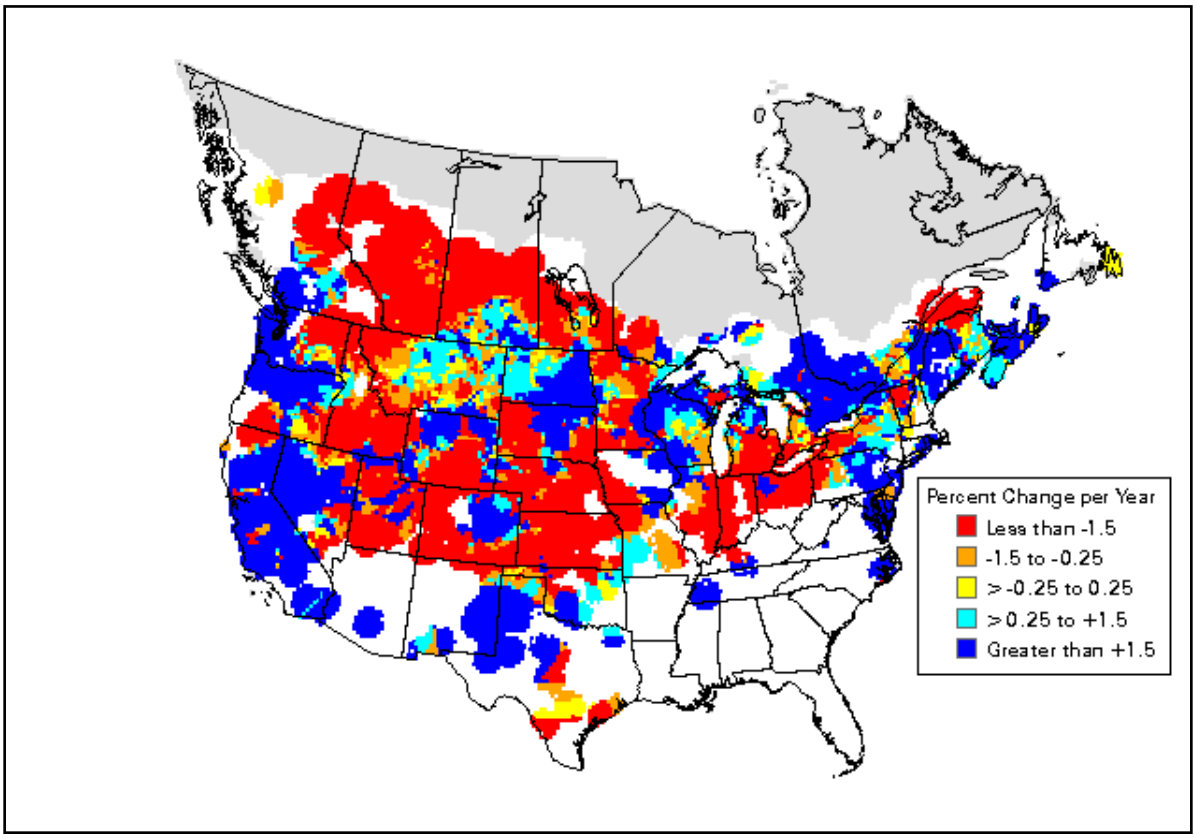

Figure 8. Northern harrier population trends (average percent population change per year) based on Breeding Bird Survey data from 1966 to 1996 (Sauer et al. 2003).

Table 2. Northern harrier population trend (percentage change per year) results based on Breeding Bird Survey trend data for the period from 1966 to 2003 (Sauer et al. 2003).

Region	Credibility measure	Trend	*P*	N
United States	Medium	-0.6	0.34	736
U.S. Fish and Wildlife Service Region 6	Medium	-1.1	0.19	303
Colorado	Medium	-1.7	0.54	39
Kansas	Low	-7.2	0	25
Nebraska	Medium	-4.8	0.22	23
South Dakota	High	-4.1	0.13	35
Wyoming	Medium	0.1	0.97	59

population declines since pre-settlement times. In the states of Region 2, 41 percent of wetlands were lost from 1780 to 1980, the majority in the mid-1900's (Dahl 1990). Conversion of grasslands for agriculture in the mid-1900's also was significant. Historical references describe the northern harrier as abundant, with a widespread distribution (Baird et al.1860, Coues 1892, Bendire 1895, Bent 1961). The number of northern harriers residing on the Great Plains continues to surpass other areas (Root 1988, MacWhirter and Bildstein 1996). However, harriers, which were formerly one of the most numerous raptors residing on the Great Plains, are now greatly out-numbered by other hawks (Carter 1998).

Activity pattern and movements

The northern harrier is a diurnal raptor, and daily activity patterns vary as a function of weather and breeding conditions (MacWhirter and Bildstein 1996). Typically, the northern harrier spends about 40 percent of its day on the wing and flies approximately 100 miles each day, often covering long distances (Root 1988). Long-distance movements are a characteristic, adaptive

feature of harrier foraging behavior, related to their highly efficient flying. Consequently, individuals are capable of exploiting habitat patches that are disjunct from breeding and wintering areas. During the breeding season, harriers may be active for up to 14 to 15 hours between dusk and dawn, with parents spending a considerable amount of time searching for food to feed their young (MacWhirter and Bildstein 1996). From pre-egg-laying to the early nestling stage the female rarely hunts and depends on the male for food (Martin 1987, Simmons et al. 1987). Adults reduce foraging activity during moderate to heavy rainfall.

Migration

Northern harrier migration activity coincides with rising air and southerly winds associated with low atmospheric pressure and the approach of a cold front (Allen et al. 1996). The northern harrier navigates behind the low pressure system in the fall, and in front during the spring migration (Haugh and Cade 1966). Migration progression occurs during daylight hours, with birds more frequently observed between the hours of 0800 and 1200, and less frequently as the day progresses (Hoffman et al. 1992). Unlike other raptors, northern harriers will continue migration during periods of light rain and snow (Haugh and Cade 1966).

The timing and departure from breeding grounds during fall migration are not well understood (MacWhirter and Bildstein 1996). Generally, fall migration within North America occurs from mid-August to late November (NatureServe Explorer 2004). Observation of migratory routes in the Great Lakes region and eastern Pennsylvania suggests that the migratory period lasts approximately three months (MacWhirter and Bildstein 1996). Northern harriers in the Rocky Mountains and Great Basin initiate fall migration earlier than birds in the eastern United States and coastal California (Binford 1979, Bildstein et al. 1984, Duncan 1986, Hoffman et al. 1992). Northern harriers breeding at higher northern latitudes may migrate farther south compared to populations that remain more or less sedentary at lower latitudes year round (Bildstein 1988). In Nebraska, peak migration occurs in October, and harriers may remain in Nebraska until snow covers their hunting grounds and forces them further southward (Sharpe et al. 2001).

Few data exist for spring migration (MacWhirter and Bildstein 1996). Most wintering sites and roosts are deserted by late February and early March, and most populations arrive on breeding grounds in March and April (MacWhirter and Bildstein 1996). At northern latitudes, arrival on the breeding grounds may be later; for example, breeding harriers in Alaska and Canada do not arrive until May (NatureServe Explorer 2004).

Sex and age differences exist for migratory behavior, and birds typically migrate solitarily or in small flocks (Craighead and Craighead 1956). During fall migration, juveniles precede adults by 30 days, and adult females precede adult males (Haugh 1972, Bildstein et al. 1984, Duncan 1986). The early departure of juveniles may allow for a more prolonged migration period with reduced daily distances, speed, and increased foraging time (MacWhirter and Bildstein 1996). During spring migration, adult males arrive on breeding grounds earlier than both adult females and juveniles (yearlings), with adult females preceding juveniles (Hamerstrom 1969, Haugh 1972, Bildstein and Hamerstrom 1980). Males arrive on breeding grounds approximately five to ten days before females (Hamerstrom 1969).

Habitat

Breeding

The northern harrier occupies a wide range of open wetland and upland habitats during the breeding season, including fresh to alkali wetlands, wet or dry grasslands, lightly grazed agricultural pastures, old fields, brushy areas, and cold desert shrub-steppe (Duebbert and Lokemoen 1977, Evans 1982, Kantrud and Higgins 1992, Prescott et al. 1995, Prescott 1997). In addition, harriers outside of Region 2 have been found breeding in young conifer plantations and early second-growth forest that succeed forest clearing (Bent 1961, Bildstein 1988). The lack of nesting records in this habitat in Region 2 may be due to preconceived perceptions of nesting habitat that have limited examination of young forest as potential nesting habitat. Determining if harriers in Region 2 ever nest in young, regrowing forest stands should be a priority for future research.

Whether nesting in dry upland or wetland habitats, harriers appear to be associated with large tracts of undisturbed habitat (MacWhirter and Bildstein 1996). In North Dakota CRP fields, northern harriers were uncommon in blocks of contiguous grassland less than 100 ha. Fragment size was not related to nest placement in Illinois, and nests were found in fragments from 8 to 120 ha (Herkert et al. 1999). However, results may have been confounded by large areas of grassland available in the surrounding landscape (Herkert et al. 1999). Harriers can likely exploit small fragments of

suitable habitat for nesting when they are situated near larger blocks of suitable habitat because of the harriers' long-distance foraging capabilities.

Microhabitat

Nests are built on the ground or over water on platforms of vegetation and are typically well concealed by tall, dense grasses, forbs or low shrubs (Hecht 1951, Duebbert and Lokemoen 1977, Hamerstrom and Kopeny 1981, Kantrud and Higgins 1992, Herkert et al. 1999). Vegetation surrounding the nest can vary in height from 0.3 to 2.1 m. In the northern Great Plains, nests were frequently located at sites with more than 40 percent residual cover, and few nests were found in areas with less than 12 percent cover (Kantrud and Higgins 1992). Although agricultural cropland and fallow fields are sometimes used for nesting, nesting success appears to be lower in these areas (Kibbe 1975). Dry shrub-steppe is rarely used for nest sites (less than 0.1 nests per 10 km^2; MacWhirter and Bildstein 1996).

Even when nests are placed in dry upland habitats, they are disproportionately positioned near wet areas such as stock ponds and streams (Simmons and Smith 1985, Grant et al. 1991). Placement of nests in wet habitats may represent a compromise between the benefits of reduced predation and the cost of reduced availability of prey (Sealy 1967, Simmons and Smith 1985). In New Brunswick, females preferred wetlands and had greater nesting success in cattails, wetland grasses (e.g., *Calamagrostis canadensis*), and prairie cordgrass (*Spartina pectinata*) compared to shrub (e.g., speckled alder [*Alnus incana*] and *Spiraea* spp.) and uplands habitats (Simmons and Smith 1985).

Breeding habitat has been examined in some states within Region 2. In Colorado, observations of northern harriers in emergent wetland marshes, short grass prairies, mountain sagebush, and croplands accounted for 52 percent of all northern harrier sightings during the Breeding Bird Atlas surveys (Carter 1998). Studies in North and South Dakota showed that 52 percent of nests (n = 27) were found in areas where vegetative cover was more than 60 cm tall, with smooth brome (*Bromus inermis*), intermediate wheatgrass (*Agropyron intermedium*), and forbs surrounding the nest site (Duebbert and Lokemoen 1977). In Wyoming, northern harriers use marshes, grass and grass-like habitats, basin prairie, and mountain-foothill shrublands (Nicholoff 2003). Results of habitat associations from many of these studies have been summarized and tabled in the comprehensive document by Dechant et al. (2003; available electronically at http://www.npwrc.usgs.gov/resource/literatr/grasbird/noha/noha.htm). We encourage users of this assessment to read this document. Here, we summarize the most important characteristics based on studies within Region 2 (**Table 3**).

Nonbreeding

In the nonbreeding season, the northern harrier uses a wide variety of open habitats with herbaceous cover, including freshwater and saltwater wetlands, grasslands, idle fields, agricultural pastureland, desert, and to a lesser extent cropland (Temeles 1986, Bildstein 1987, Collopy and Bildstein 1987). Some of the most concentrated populations occur in the grasslands of the southern Great Plains, especially in eastern Colorado, Nebraska, and central Kansas (MacWhirter and Bildstein 1996). An important component of nonbreeding habitat

Table 3. Habitat characteristics associated with northern harriers in USDA Forest Service Region 2 (Dechant et al. 2003).

Author	Location	Habitat	Habitat Characteristics
Kantrud and Kologiski (1982)	CO, MT, NE, ND, SD, WY	Mixed-grass pasture, shortgrass pasture, shrubsteppe	Lightly to moderately grazed areas; vegetation averaged 23 to 30 cm in height.
Kantrud and Higgins (1992)	MT, ND, SD	Tame, cropland, hayland, idle mixed-grass pature, tame pasture	Grasslands or native prairie dominated by brush, especially western snowberry (Symphoricarpos occidentalis). Nested in vegetation >55 cm with > 40% residual litter and avoided areas with < 12% residual litter.
Luttschwager and Higgins (1992)	SD	Idle seeded-native, idle tame, seeded-native hayland, tame hayland	Nested in idle strips and block within mowed fields.
Zimmerman (1993)	KS	Burned tallgrass, idle, idle tallgrass, woodland	Nest found in unburned prairie, but foraged in burned and unburned areas.

for northern harriers is communal roost sites, of which locations are often traditional (Evans 1982, Bosakowski 1983, Bildstein 1988). Between late October and early May, northern harriers roost on the ground in groups of two to 85 (average = 20) individuals. Individual members of the roost occupy small patches (no more than 0.25 m^2) of open ground that are joined by short runways about 2 meters apart (Bildstein 1988).

Foraging

Because the northern harrier uses vegetation and terrain to surprise its prey, preferred foraging habitat consists of open areas with moderate to heavy vegetative cover (i.e., prairies, shrub-steppe uplands, marshes, and inactive fields not heavily grazed or harvested by farmers; Linner 1980, Bildstein 1987, Preston 1990, MacWhirter and Bildstein 1996). Favored hunting habitat is a function of both prey abundance and vegetation density (Preston 1990). Presumably, few rodents are available in bare to sparse vegetative cover; however, with increasing vegetation density, small rodents likely become less vulnerable to detection and capture, and thus hunting efficiency decreases (Collopy and Bildstein 1987). Foraging habitat differs slightly between females and males, with females hunting more in taller and denser vegetation (Bildstein 1987). Males use more open habitats than females for several reasons:

- their favored prey, birds, are more abundant and easier to capture in open habitats (Bildstein 1987)
- females have smaller home ranges, and thus habitat preferences are more similar to those surrounding the nest site (Martin 1987)
- females exclude males from preferred hunting habitats in the winter (Temeles 1986).

Food habits

The northern harrier hunts for food on the wing, coursing low (less than 5 m) during daylight hours to capture prey on the ground or snatch it out of low, shrubby vegetation (MacWhirter and Bildstein 1996). The diet of the northern harrier depends on prey abundance, but it consists mainly of small mammals, especially *Microtus* spp. and cotton rats (*Sigmodon hispidus*), and to a lesser extent, small and medium-sized birds (e.g., northern flicker [*Colaptes auratus*], meadowlark [*Sturnella* spp.], red-winged blackbird [*Agelaius phoeniceus*], bobolink [*Dolichonyx oryzivorus*]), snakes, frogs, insects, crustaceans, and carrion (Sutherland 1987, MacWhirter and Bildstein 1996).

Food habits differ with respect to age and sex. Adult males prey more on birds (40 versus 4 percent for females), whereas females and juveniles prey more on small mammals (93 versus 56 percent for males; Bildstein 1987). The diet of recently fledged juveniles also consists of insects (MacWhirter and Bildstein 1996). In general, adult males are more successful in prey capture compared to adult females, and juveniles are less successful than adults (Toland 1986a, Bildstein 1987). Successful prey captures commonly decrease with agility of prey (amphibians and reptiles 74 percent, small mammals 34 percent, birds 14 percent; Toland 1986a, Bildstein 1987). Food delivered to nestlings and dependent fledglings typically consists of small mammals and birds (Barnard et al. 1987, Redpath et al. 2001).

Geographical differences in food habits correspond with prey abundance and availability. Harriers wintering in the northern part of their range prey almost entirely on *Microtus* spp. (84 to 93 percent), and to a lesser extent, on deer mice (*Peromyscus maniculatus*), house mice (*Mus musculus*), shrews (*Soricidae*), rabbits (*Sylvilagus*), and passerine birds (e.g., meadowlarks, northern cardinals [*Cardinalis cardinalis*], and song sparrows [*Melospiza melodia*]) (Bildstein 1987). Birds wintering in the southern United States prey mostly on mammals including cotton rats and house mice, and to a lesser extent, harvest mice (*Reithrodontomys* spp.), rice rats (*Oryzomys palustris*), shrews, and passerine birds (e.g., meadowlarks and northern cardinals) (Jackson et al. 1972, Preston 1990). Although somewhat variable among studies, generally, the proportion of passerine birds in northern harrier's diet is higher in southern parts of the winter range (more than 15 percent) compared to northern parts of the winter range (less than 10 percent; Jackson et al. 1972, Preston 1990). In areas where small mammals are less abundant, such as the southeastern coastal marshes, northern harriers hunt passerines and waterbirds (Collopy and Bildstein 1987).

Northern harriers are flexible and opportunistic in their diet, especially during the nesting season, in response to variation in the abundance and availability of different food types (Bildstein 1988, MacWhirter and Bildstein 1996). Although voles (*Microtus* spp.) predominate in the diet in many areas, harriers are not obligate specialists on rodent prey; small birds can make up the majority of prey items under some conditions. In areas where voles are abundant, they constitute 95 percent of the harrier's diet in outbreak years, and

75 percent of the diet in years when the cycling vole population is low (Root 1988). Inadequate food supply in some areas may contribute to nomadic behavior. For instance, within Region 2, northern harriers were absent in Kansas when rodent abundance was low in the winter of 1983-1984 (Zimmerman 1993).

Breeding biology

Phenology

The northern harrier breeding season generally begins in mid-March to early April and lasts approximately 120 to 135 days (MacWhirter and Bildstein 1996). In Colorado, and probably other states in USFS Region 2, breeding begins in late April (Colorado Partners in Flight 2000). Pair formation appears to begin on the breeding grounds, and courtship rituals involve a series of aerial and territorial displays (Hamerstrom 1986, MacWhirter and Bildstein 1996). Northern harriers are generally monogamous, but polygyny with well-structured hierarchical harems of two to five females has also been reported (Balfour and Cadbury 1979, Hamerstrom et al. 1985, Simmons et al. 1986b). In New Brunswick, Wisconsin, and Washington, 11 to 14 percent of males were polygynous, 20 to 29 percent of females mated within a harem, and the remaining population mated monogamously (Thompson-Hanson 1984, Hamerstrom et al. 1985, Simmons et al. 1986b). There is little evidence that a female-biased adult sex ratio favors a polygynous mating system in harriers (Simmons 1988). Instead, variation in male quality, related to courtship display and food provisioning, influences female mate choice, and thus the most vigorous males acquire the largest harems (Simmons 1988). The incidence of polygyny is positively associated with vole abundance (Hamerstrom 1970, Simmons et al. 1986a,b). Females occasionally abandon prospective male partners with low courtship provisioning rates (Simmons 1988).

Nest structures from previous years are generally not used in successive breeding attempts; however, northern harriers may return to breed in the same general area in following years (Hamerstrom 1969, Burke 1979). In Wisconsin, 30 to 36 percent (n = 88) of banded breeding adults returned to their nesting area in subsequent years (Hamerstrom 1969, Burke 1979). Previously successful male and female breeders were more likely than failed breeders to return to former breeding sites (Hamerstrom 1969, Burke 1979).

Nest sites are chosen by females, males, or by both sexes, and site selection is incorporated into courtship rituals (Toland 1985b). Nest building may take several days to two weeks and is a cooperative effort by both sexes (MacWhirter and Bildstein 1996). An assortment of dead grasses, weeds, reeds, and small twigs are collected near the nest site (Bent 1961). The inner portion of the nest is lined with grasses, sedges, and rushes. In Wyoming, nest platforms were made of thick-stalked cattail, alder, and willow (Nicholoff 2003).

Clutch size, incubation, and parental care

Northern harrier clutch size varies between four and six eggs (mean = 4.4, n = 1,174) that are laid at two-day intervals (Bent 1961, MacWhirter and Bildstein 1996). There is no indication of geographical variation in clutch size (MacWhirter and Bildstein 1996). In New Brunswick, egg laying occurred earlier during years of high vole abundance and high prehatch provisioning rates by males (Simmons et al. 1986a,b). Older females and primary females in polygynous mating systems lay their eggs earlier than younger and secondary females (MacWhirter and Bildstein 1996).

Northern harriers typically lay one clutch per breeding season. In cases where nests are destroyed or deserted during egg laying, replacement clutches are occasionally laid in a newly constructed nest and in some instances on a former nest platform (Duebbert and Lokemoen 1977, Simmons 1984). Human disturbances (e.g., recreational activities, agricultural operations, frequent visitation by researchers and the public) can result in nest abandonment (Hamerstrom 1969, Fyfe and Olendorff 1976). Infrequent renesting has been observed in New Brunswick (Simmons 1984), Michigan (Craighead and Craighead 1956), and the Dakotas (Duebbert and Lokemoen 1977). In Michigan, one pair out of eight (13 percent) renested following nest destruction (MacWhirter and Bildstein 1996), and of nine renest attempts after failure, 44 percent of females used the same territory (MacWhirter and Bildstein 1996).

The incubation period lasts approximately 30 to 32 days and begins before the last egg is laid (Breckenridge 1935, Hamerstrom 1969). Only females incubate (Hamerstrom 1969). During the early phase of the incubation period, the female rarely leaves the nest and relies heavily on her mate for assistance with food delivery. Male parental care duties involve nest provisioning and delivering food to the young (Simmons 1988). The amount of time that females spend foraging for nestling food is inversely proportional to her mate's provisioning rate (Simmons et al. 1987). Males supply monogamous and primary

broods with about 67 percent of the food items during the nestling period, and they provide progressively smaller proportions of food to broods of later-settling harem females (Saunders 1986). Under polygynous conditions, secondary females must therefore contribute more time and energy towards hunting and delivering food to young compared to monogamous or primary females (Simmons et al. 1987).

Nestlings hatch asynchronously mid-May to early June (MacWhirter and Bildstein 1996). The nestling stage of development lasts approximately 30 to 41 days (Hamerstrom 1969). At 30 days, young gain the ability to fly short distances but remain close to the nest site. Generally, the age at first flight is inversely proportional to growth in body mass and tail length; lighter fledglings and those with well-developed flight feathers, typically males, are the first to fledge (MacWhirter 1994). In Colorado, young leave the nest by August (Colorado Partners in Flight 2000).

Demography

Genetic characteristics and concerns

No studies to examine genetic diversity among and within subspecies and populations have been conducted. With a widespread and mostly contiguous distribution in North America and a somewhat nomadic lifestyle, it is unlikely that northern harriers suffer from genetic issues related to small populations. However, the continued loss and fragmentation of grassland and wetland habitats may have genetic consequences in the future. Habitat loss and fragmentation isolates and creates smaller populations, which, in turn, increases the likelihood of local extinctions, decreases the probability of colonization, and genetically isolates populations. This leads to increased probabilities of inbreeding and genetic drift, and a lowering of genetic diversity. Fragmentation can potentially turn continuous populations into "metapopulations of semi-independent demes" that gradually disappear (Risser 1996).

Life history characteristics

Males, and more commonly, females begin breeding in their first year of life (Hamerstrom et al. 1985). Given their complex breeding system and their strong association with a cyclical prey item, it is not surprising that annual reproductive success is highly variable. The median number of offspring fledged per pair is 2.1 (n = 13 studies; MacWhirter and Bildstein 1996). The only published study from Region 2 occurred in North and South Dakota and reported a nesting success (probability of fledging at least one young) of 65 percent (n = 20) (Duebbert and Lokemoen 1977).

The strongest factors influencing reproductive success are male food-provisioning rate, nest initiation date, and to a lesser extent, clutch size (Simmons et al. 1986a, Barnard et al. 1987). Monogamous and primary females of polygynous males have higher reproductive success than secondary females of polygynous males (Simmons et al. 1986b). This is largely attributed to higher male-provisioning rates (Simmons et al. 1986b). In addition, secondary females in polygynous systems lay smaller clutches compared to primary females and monogamous pairs, a phenomenon that has been explained by the tendency for clutch size to decrease as the season progresses (Simmons et al. 1986b). In New Brunswick, polygynous males produce about 62 percent more offspring than monogamous males (Hamerstrom et al. 1985, Simmons 1988). Although polygyny appears to be reproductively advantageous to males that practice it, one of the costs of polygynous mating is a higher incidence of nonhatched eggs (Simmons 2000). In New Brunswick, polygynous males gave rise to 1.6 times as many nonhatched eggs as monogamous males (11.5 versus 4.8 percent; n = 302), a pattern best explained by sperm depletion due to polygynous males copulating with many females (Simmons 2000).

Adequate information on northern harrier lifespan and survivorship is lacking; no study has measured adult or juvenile survivorship. The longest recorded life span of a free-ranging northern harrier is 16 years and 5 months (Clapp et al. 1982). Due to the absence of data on survivorship and the complexity of the northern harrier breeding system, we did not create a life cycle diagram or perform a matrix population analysis. Although these types of analyses can illuminate certain aspects of the population biology of a particular species, the creation of models with incomplete data is equally likely to provide irrelevant or misleading results (Reed et al. 2002).

Home range and territory size

During the breeding season, home range size varies among sites due to differences in food availability and habitat quality (range = 170 – 15,000 ha, median = 260 ha, n = 8 studies; MacWhirter and Bildstein 1996). Males may hunt more than 10 km from the nest, with ranges overlying those of other males (Barnard 1983, Thompson-Hanson 1984). Females commonly occupy

smaller home ranges than males and forage closer to the nest (Craighead and Craighead 1956, Thompson-Hanson 1984, Martin 1987).

Northern harriers may nest alone or in loose assemblages (MacWhirter and Bildstein 1996). Territorial behavior is minimal during the breeding season, except at the nest site where both males and females will defend their territory against conspecific intruders (Martin 1987, Simmons et al. 1987). Defense behavior is most vigorous during courtship and incubation periods (Martin 1987, Simmons et al. 1987). Territory size, internest distances, and distribution of nests are variable among and within populations in response to the incidence of polygyny, habitat quality, and prey abundance (MacWhirter and Bildstein 1996). In polygynous territories, internest distances among harem members are shorter than between independent breeders (MacWhirter and Bildstein 1996). The distance between nest sites is typically between 243 and 2400 m (median 430 m, n=7 sites) and nests are rarely closer than 100 m (MacWhirter and Bildstein 1996). In Colorado, northern harriers territory size is approximately 2.6 to 3.9 km^2 (Carter 1998).

Home range size during the nonbreeding season is poorly studied. In Michigan, Craighead and Craighead (1956) found northern harrier hunting range sizes from 0.12 to 2.6 km^2. The area used by northern harriers on wintering grounds includes communal roosting sites. Roost sites, which are on the ground, are chosen with respect to the density of prey in the area and are located at the midpoint of hunting areas (Bildstein 1979). One roost normally holds about 20 birds, with each bird occupying a small ($\leq$ 0.25 m^2) patch of open ground in grassy or stubble fields (Bildstein 1988). The same roosting site is used anywhere from several nights to several months (Craighead and Craighead 1956, Bent 1961) and may be revisited annually (Bosakowski 1983, Christiansen and Reinert 1990).

Winter territories in the southeastern United States were defended from several hours to more than 15 days and averaged approximately 65 ha in size. (Collopy and Bildstein 1985). Due to their larger size, adult females secure preferred foraging areas and defend territories against conspecific intruders (Temeles 1986). In response, males and subordinate females may switch to alternative foraging behavior, or forage in low-quality areas (Temeles 1986).

Factors limiting population growth

The availability of large tracts (greater than 100 ha) of open wetland and idle grassland habitats for nesting and foraging appears to be the most important factor regulating northern harrier populations. Although cropland and fallow fields are sometimes used as nest sites, nesting success appears to be lower in these areas compared to undisturbed wetlands and grasslands (Kibbe 1975). Harriers prefer nesting in wetlands and have higher nesting success in cattails, wetland grasses, (*Calamagrostis canadensis*) and prairie cordgrass compared to shrubs (e.g., speckled alder and meadow-sweet) and uplands (Simmons and Smith 1985).

Because reproduction appears to be related to the availability of prey, particularly small mammals, factors that influence prey abundance are also important. In general, habitats used by harriers and many of the prey species upon which they depend are similar. Small mammals prefer undisturbed grasslands and fields with dense vegetative cover (Birney et al. 1976, Baker and Brooks 1981). Overgrazing of grasslands and increases in monotypic, heavily tilled cropland severely limit the availability of suitable prey habitat. In addition, pest control using insecticides and rodenticides reduces vole abundance (Duebbert and Lokemoen 1977, Hamerstrom 1986).

During the winter, factors affecting local abundance of harriers include prey availability and weather (e.g., snow cover and temperature). Information on the importance of roost-site availability to harrier populations is lacking, but considering that many roost sites are traditional, their protection may be important to maintain local populations.

Community ecology

Predators

Nest predation by terrestrial mammals is probably the primary cause of nest failure, but documented accounts are lacking. Important nest predators likely include coyote (*Canis latrans*), feral dog (*C. familiaris*), striped skunk (*Mephitis mephitis*), mink (*Mustela vison*), raccoon (*Procyon lotor*), and red fox (*Vulpes fulva*; MacWhirter and Bildstein 1996). In addition, canid predators may kill incubating females. Avian nest predators likely include American crows (*Corvus*

brachyrynchos) and common ravens (*C. corax*), and great horned owls (*Bubo virginianus*) kill nestling and fledglings (Simmons et al. 1986a, Toland 1986b, Sutherland 1987). Many of these nest predators are associated with and more common in, fragmented and edge habitats. Like forest nesters, grassland-nesting birds have reduced fecundity in smaller habitat fragments because of increased nest predation close to an edge, particularly if one of the edge habitats is dominated by woody species (Johnson and Temple 1990). The loss and fragmentation of wetland and grassland habitats in Region 2 and in other parts of its range have likely led to increased predation pressure on nesting northern harriers.

The incidence of nest predation also varies in response to food availability, which mediates the degree of nest guarding by breeding pairs (MacWhirter and Bildstein 1996). In New Brunswick, egg and nestling predation decreased during periods of high vole abundance (Simmons et al. 1986a). Predation rates were also higher for secondary females in polygynous mating systems compared to monogamous and primary females because lower male-provisioning rates force secondary females to leave their nest unguarded more frequently to forage (Simmons et al. 1986a,b, MacWhirter and Bildstein 1996).

Competitors

Northern harriers are fairly subdued during interactions with competitor species. The northern harrier avoids hunting during times when activity levels and densities of *Buteo* hawks are high (Bildstein 1987) and does not defend prey against larger *Buteos* (MacWhirter and Bildstein 1996). Similarly, the northern harrier avoids areas occupied by rough-legged hawks to avoid losing captured prey to this species (Collopy and Bildstein 1985, Bildstein 1987). During the breeding season, home range territories of the northern harrier may overlap with short-eared owls (Linner 1980), and harriers on occasion will kleptoparasitize food from them. However, because preferred prey of these species differs, interactions are generally quite restricted (MacWhirter and Bildstein 1996).

Parasites and disease

There are few data on the long-term effects of parasites and disease on northern harrier populations because of the difficulty in establishing whether mortality is directly or indirectly related to infection by parasites and disease (Newton 1979). Internal and external parasites that have been known to inflict northern harriers include biting lice (*Colpocephalum flavescens*, *Degeeriella fusca*, *Philopterus taurocephalus*) and hippoboscid louse flies (*Lynchia americana*, *Ornithomyia fringillina*, *Ornithoica vicina*) (Serrentino 1992). Ingestion of mice infected with fowl cholera bacterium leads to the death of northern harriers (Rosen and Morse 1959). Generally, the incidence of insect-borne haematozoa (*Haemoproteus*, *Leucocytozoon*, *Plasmodium*) is lower in northern harrier compared to other North American birds (Greiner et al. 1975, Peirce et al. 1990).

Envirogram

Figure 9 shows an envirogram for the northern harrier that represents the ecological relationships between the species' demographics, its habitat requirements, and its predator and competitors that occur in Region 2. The linkages should be viewed as a series of hypotheses based on the ecology of northern harriers that land managers can consider when evaluating management options (Andrewartha and Birch 1984).

CONSERVATION

Threats

The northern harrier has a widespread distribution in North America and within Region 2, inhabiting a broad range of open wetland and grassland habitats as long as large tracts of tall, dense herbaceous vegetation are present. As evidenced by the low credibility values assigned to BBS population trend data, harrier populations have been difficult to monitor because of their relatively low density and propensity to shift breeding sites among years in response to prey availability. Nevertheless, there is substantial evidence that populations have declined, significantly in some locations, and these declines are primarily attributed to habitat loss, habitat fragmentation, and degradation of breeding and nonbreeding habitat (MacWhirter and Bildstein 1996). Specific threats to northern harrier habitat and its populations are discussed below. The lack of information on northern harrier demographics, minimum area requirements for sustainable populations, or meta-population dynamics, limits our ability to directly assess threats in terms of population viability. Consequently, we focus our discussion of threats to effects on individuals and habitat quality and availability; where appropriate, population effects are discussed.

Habitat loss of wetlands and grasslands, principally to agriculture and urban development,

WEB 4	WEB 3	WEB 2	WEB 1	RESOURCES CENTRUM
	grassland and wetland habitats	absence of fire, grazing, other disturbance	tall, dense vegetation	food: small mammals
grassland and wetland habitats	human development	habitat fragmentation	predator community	food: small mammals
			winter precipitation	food availability
	grassland and wetland habitats	absence of fire, grazing, other disturbance	tall, dense vegetation	nesting and foraging habitat
		wetland habitat	drainage	nesting and foraging habitat

Figure 9a. Resources centrum for the northern harrier envirogram.

WEB 4	WEB 3	WEB 2	WEB 1	MALENTITIES CENTRUM
		water/weather	wetland habitat	fecundity, density
grassland and wetland habitats	human development	habitat fragmentation	predator community	fecundity, density
	grassland and wetland habitats	absence of fire, grazing, other disturbance	tall, dense vegetation	fecundity
	grassland and wetland habitats	human development	habitat fragmentation	population decline
		humans	pesticides	fecundity, density, population decline

Figure 9b. Malentities centrum of the northern harrier envirogram.

has contributed to harrier declines and likely remains the most important threat to local northern harrier populations. Undoubtedly, the loss of wetlands through the late 1900's has played a significant role in the decline of northern harriers. Within Region 2, approximately 41 percent of wetlands were lost prior to 1980, mostly to agricultural conversion (Dahl 1990). Over the last two decades, the rate of wetland loss in Region 2 and the United States has slowed considerably due to increased federal protection and conservation programs, such as the Wetland Reserve Program and the CRP, that create and restore wetland habitats. These programs promote partnerships among government, conservation groups, and private landholders and have likely benefited harriers. However, wetland loss still occurs, and in Colorado, Andrews and Righter (1992) identified the continued loss of wetland habitats as the greatest threat to northern harrier populations.

The conversion of grasslands for agricultural purposes may be a more significant threat to local harrier populations than the loss of wetlands because grasslands lack federal regulatory protection and less than 1 percent are in public ownership (Samson and Knopf 1994). Northern harriers tend to avoid agricultural areas because the vegetation features they prefer for nesting and foraging habitat (tall, dense vegetation) are absent. When harriers do nest in agricultural habitats, reproductive success is generally low due to farming activities that destroy nests or cause nest abandonment and high predation rates (Hamerstrom 1969, Kibbe 1975, Dechant et al. 2003) (Native grasslands have

experienced significant losses over the last 200 years, mostly due to agricultural development (Samson and Knopf 1994, Noss et al. 1995). Mesic grasslands (i.e., tall- and mixed-grass prairies) are most vulnerable because soils, climate, and precipitation make row crops more economically viable (Steinauer and Collins 1996). In the eastern Great Plains, less than 4 percent of the tallgrass prairie remains. Within Region 2, the vast majority of the tallgrass prairie type is found in the states of South Dakota, Nebraska, and Kansas (Samson and Knopf 1994). Relative to mesic grasslands, the loss of shortgrass habitats to agriculture is not as pervasive because arid conditions are less suitable for farming. Still, nearly 32 percent of the shortgrass prairie region (including 31 percent in Colorado, 78 percent in Kansas, 65 percent in Nebraska, and 12 percent in Wyoming) has been converted to cropland (Samson and Knopf 1994, Knopf and Rupert 1999). Moreover, future technological advances, such as improved irrigation systems and the development of seed sources capable of growing in arid environments could open up currently unfarmable grasslands.

Urban development is also becoming an increasing threat to northern harrier habitat. For example, in the shortgrass habitats of the Front Range Corridor in Colorado human population densities have increased to 1,180 people per km^2 in the counties of Denver, Boulder, Jefferson, Arapahoe, Larimer, and Douglas compared to the 0.4 to 6.6 people per km^2 found outside of the corridor (Colorado Partners in Flight 2001). Habitat loss through urbanization may be a more important threat than agricultural conversion because its impacts are permanent and irreversible, unlike those of cropland conversion, which has the potential to be restored to its original condition. As human populations increase and urban areas expand further into the prairie ecosystem of Region 2, loss of grassland habitat, particularly around existing population centers, will continue to have significant implications for local northern harrier populations.

Coupled with habitat loss is the increased level of fragmentation of native habitats, which has negative consequences for the northern harrier. Northern harriers are characterized as an area-sensitive species with large home ranges (Martin 1987), and they are usually associated with larger (more than 100 ha) tracts of undisturbed habitat (Johnson and Igl 2001). Although there is some uncertainty regarding how fragment size and distribution influence harriers, fragmentation appears to negatively affect harriers by 1) reducing prey density through increased predation from other predators, such as canids and raptors, and 2) increasing the costs of foraging by harriers, who must travel farther distances and have larger home ranges to support themselves. These factors, in turn, reduce the frequency of mate-feeding, which is negatively related to reproduction output. Fragmented habitats can also cause lower reproductive output by harriers because it increases their increased susceptibility to nest predation. Fragmented habitats usually support more diverse predator communities than interior habitats because of the increased proportion of edge habitats (Johnson and Temple 1990).

Fragmentation is not an issue restricted to private lands, as fragmentation on public lands can be severe as well. In 1995, a study found that Thunder Basin National Grassland in Wyoming contained 338 grassland fragments less that 2.6 km^2 (Senner and Ladd 1996). Although some consolidation has occurred, the number of fragments remains high due to numerous mineral and grazing leases. Not only does this negatively impact grassland bird populations such as the northern harrier, but it also decreases the USFS's ability to manage effectively for species conservation and to provide an effective demonstration site for private landholders (Senner and Ladd 1996).

In Region 2, northern harriers prefer to nest in tall vegetation with dense litter cover. Agricultural activities that remove vegetation, such as grazing, mowing, and haying, can either make habitat unsuitable or lower habitat quality, leading to local population declines and reduced reproductive output. Northern harriers that nest in suboptimal habitats with less protective vegetative covering are more susceptible to predation and are less likely to be successful (MacWhirter and Bildstein 1996). Because northern harriers nest on the ground, agricultural practices during the breeding season can cause nest abandonment or directly destroy nests (Hamerstrom 1969, Fyfe and Olendorff 1976). Since northern harriers normally make only one nesting attempt each year, these actions reduce annual reproductive success and may contribute to population declines (Bildstein and Gollop 1988).

Northern harriers avoid heavily grazed areas, and overgrazing is a significant threat to harrier habitats. In response to increased grazing pressure, northern harriers have reduced their use of livestock-grazed grasslands in the Great Plains, the Southwest, and the Intermountain West (Linner 1980, Bildstein 1987, Bock et al. 1993). However, northern harriers will use light to moderately grazed lands when adequate cover is retained (Kantrud and Kologiski 1982, Bock et al. 1993). Grazing is ubiquitous within Region 2, particularly in mixed- and

shortgrass habitats. Conservation efforts that work to reduce grazing pressure, such as deferring grazing until after the breeding season and limiting grazing during other times of the year, will benefit harriers.

Agricultural activities that eliminate vegetative cover also contribute to local population declines and lower reproductive output by reducing the availability of northern harrier prey. Small mammals are more abundant in areas of dense vegetative cover, such as undisturbed grasslands and idle fields (Birney et al. 1976, Baker and Brooks 1981). Prey availability is directly related to northern harrier density in both the breeding and the nonbreeding seasons (Craighead and Craighead 1956, Grant et al. 1991, Busby and Zimmerman 2001). Both clutch size and reproductive success are also correlated to prey availability (Burke 1979, Hamerstrom et al. 1985, Simmons et al. 1986a).

Fire is a natural disturbance process necessary for the maintenance of grassland ecosystems and their avifauna in Region 2. However, when natural patterns of fire are altered, they can negatively impact the quality and availability of northern harrier habitat. As a process, fire works primarily through removing standing vegetation and litter and increasing nutrient cycling rates (Bragg and Steuter 1996), and thus its impacts are similar to those described above under grazing, mowing, and haying. Fire effects on vegetation, and subsequently wildlife, vary with respect to grassland type, season, intensity, frequency, and local climate (Bragg and Steuter 1996, Steinauer and Collins 1996, Weaver et al. 1996).

The application of fire at intervals that do not allow for the development of moderate to heavy herbaceous cover, features that northern harriers prefer, is a threat to harriers. In all grassland habitats, the use of fire is immediately detrimental to harriers as it reduces litter accumulation and may destroy nests if conducted during the breeding season. Frequent fire is more detrimental in mixed- and shortgrass habitats because these grasses recover slowly, requiring two to three years with normal precipitation; during periods of drought, vegetation will take longer to recover (Wright and Bailey 1980). In tallgrass habitats, the effect of fire is not as severe because the less arid conditions and more organic soils allow grasslands to recover quickly. Prior to Euro-American settlement, fire was a frequent disturbance factor in tallgrass habitats, with an average interval of two to five years (Steinauer and Collins 1996). Although less is known about the natural frequency of fire in mixed- and shortgrass prairie communities, it was probably much less frequent than in tallgrass communities (Weaver et al. 1996). In general, fire applied at natural intervals, outside of the breeding season will likely benefit harriers and other grassland birds.

Shooting by humans was historically one of the largest sources of northern harrier mortality and likely still remains a threat to the species (Bildstein 1988, MacWhirter and Bildstein 1996). Of 197 young banded in Wisconsin and North Dakota during the mid-1900's, 19 of 28 (68 percent) individuals that were subsequently recovered had been shot (Bildstein 1988). Northern harriers are vulnerable to shooting due to their ground-nesting and communal-roosting habitats and their low hunting flight. Although existing laws provide legal protection, shooting pressure likely remains a threat to northern harriers, especially for birds congregating at winter communal roosts (MacWhirter and Bildstein 1996).

Raptors, such as the northern harrier, are relatively long-lived and maintain high positions in food webs, making them susceptible to deleterious effects associated with bioaccumulation of pesticides, pollutants, and their metabolites (Ehrlich et al. 1988). The use of pesticides, primarily DDT, in the mid 1900's contributed to northern harrier population declines (Hamerstrom 1986, Wheeler 2003). Although DDT was banned in the 1970's, organochlorine levels sufficient enough to cause egg shell thinning were found in harrier tissues in the 1980's (Noble and Elliot 1990). Consequently, pesticides have been suggested as a contributing component in the continuing decline of harrier populations in some areas of Region 2 (Nicholoff 2003). Northern harriers are susceptible to organophosphate poisoning from rodent control, and in some areas, levels of organophosphates have remained traceable in northern harriers (Wheeler 2003).

Conservation Status of the Species in Region 2

Sufficient evidence exists to suggest that the northern harrier should be considered a species of concern in Region 2. Although the northern harrier has a wide distribution across North America, populations have declined range-wide in the twentieth century (Evans 1982, Tate 1986, Serrentino 1992). The decline appears to have been greatest during the early to mid-1900's due to the loss of wetlands and increased exposure to pesticides. Since the 1960's, the North American population has declined at a slower rate (MacWhirter and Bildstein 1996, Sauer et al. 2003). However, BBS and CBC data suggest that strong

regional declines are still occurring in the Great Plains region, which represents the core of this species' range and includes much of Region 2. Since 1966, BBS data indicate population declines of 4.8, 4.1, 1.7 percent per year in Nebraska, South Dakota, and Colorado, respectively; however, data from all states except South Dakota are of low creditability (Sauer et al. 2003). Consequently, statistical power for trends within these states is weak and represents uncertainty in the ability to accurately assess the conservation status of this species. Nevertheless, given the significant loss of wetlands and grasslands over the last two decades, and the extensive amount of overgrazing in Region 2 (see Threats section), populations in Region 2 remain at risk to continued declines and local population extirpations.

Studies from Region 2, and elsewhere, suggest that land management activities influence the suitability of habitats for northern harriers. However, patterns of habitat use by harriers are mostly inferred from comparative studies of abundance and not demographics. Thus, linkages between habitat variability (due to habitat management) and population viability are poorly understood. Habitat patch size appears to be an important factor in habitat suitability for northern harriers. Studies have documented northern harrier avoidance of small blocks of contiguous grassland (less than 100 ha; Johnson and Igl 2001). However, it is unclear how patch size and patch distribution interact to affect local northern harrier populations.

The northern harrier inhabits a wide array of habitat types, but within those habitats, it depends upon a rather specific set of vegetation conditions that make it vulnerable to land use practices in Region 2. Northern harriers require breeding habitats with dense residual cover and areas of moderate to heavy cover during the nonbreeding season as foraging habitat (Hamerstrom and Kopeny 1981, Kantrud and Higgins 1992, MacWhirter and Bildstein 1996). They avoid habitat patches where moderate to heavy grazing keeps vegetation heights low. A study by Samson et al. (2003) indicates that grazing pressure on national grasslands in Region 2 has created large areas of grasslands in short structural size classes. Medium and tall grass heights, which harriers require, are strongly underrepresented (Samson et al. 2003). Haying and mowing mimic grazing pressure, and their application can also reduce habitat quality for northern harriers.

The northern harrier's nesting ecology also may contribute to this species' vulnerability. Typically, this species makes one breeding attempt per year, rarely renesting after failure. In addition, there is evidence that in grassland habitats, ground-nesting birds, such as the northern harrier, suffer higher predation rates than birds nesting in off-ground habitat layers, particularly in disturbed habitats (Martin 1993). These aspects of its life history may reduce the species' ability to recover from local population declines that result from changes in habitat availability and quality, subsequent increases in nest predation, and environmental variation, increasing the likelihood of local population extirpations.

Overall, the likelihood of extirpation within Region 2 is low because of the northern harrier's widespread distribution. However, considering the long-term declines in Region 2 over the twentieth century and its specific habitat requirements and ecological characteristics that make it vulnerable to land management actions, the northern harrier deserves consideration as a species of concern. Without active management of wetland and grassland habitats aimed at maintaining populations of northern harriers, local extirpations are likely to occur with increasing frequency.

Potential Management of the Species in Region 2

Implications and potential conservation elements

Northern harriers require large areas of undisturbed wetland and grassland habitats for nesting and foraging purposes. Yet, the cumulative historic and ongoing impacts of habitat loss, fragmentation, and degradation from land management practices that fail to replicate natural disturbance processes have severely reduced the availability and quality of wetland and grassland habitats in Region 2. Consequently, northern harrier populations appear to have declined significantly since Euro-American settlement. In much of Region 2, northern harrier populations continue to exhibit moderate declines, whereas in most other parts of its range, declines have subsided. Unfortunately, acquiring robust population trend data is difficult for this species due to its low density and tendency toward nomadic behavior. These characteristics have also led to few studies attempting to uncover the relationships between northern harriers and land management activities. Few management programs have been described for this species. Current management approaches specifically concerned with northern harrier conservation suggest that increasing the availability of wetlands and ungrazed grasslands will serve to both increase the amount of suitable foraging and nesting habitat and decrease the incidence and severity of

habitat fragmentation. One area not addressed in most management recommendation documents is the identification and protection of winter communal roost sites. Although there is no evidence that these sites are currently limited, they are traditional and would likely prove to be an effective conservation measure for this species. Overall, conservation in Region 2 will require a renewed emphasis on creating the necessary landscape matrix and habitat conditions needed to support this species.

Federal protection of national grasslands within USFS Region 2 provides significant tracts of undeveloped grassland and wetland habitats. However, natural land disturbance patterns are not always adequately replicated in these areas, resulting in negative consequences for northern harriers. The use of grazing as a land management technique is common among all national grasslands (Cable et al. 1996), but overgrazing is frequently indicted as a primary cause of habitat degradation (Bock et al. 1993, Samson et al. 2003). Overgrazing is a threat to northern harriers because they require tall, dense grass and emergent vegetation to nest in grassland and wetland habitats (Simmons and Smith 1985, Sutherland 1987, Kantrud and Higgins 1992, MacWhirter and Bildstein 1996). On four Region 2 national grasslands, medium and tall grass structural size classes were significantly underrepresented (Samson et al. 2003). Grazing regimes that better manage for the natural proportion of grass structural stages would benefit northern harriers. Furthermore, by serving as demonstration sites and promoting management activities that maintain their land's biotic integrity, national grasslands can serve as effective role models for private landowners.

Intermittent disturbance processes that remove vegetation, such as grazing or fire, may be necessary to maintain suitable habitat by halting succession and stimulating plant growth. Disturbance processes may initially create less suitable habitats for northern harriers and their prey populations. As a result, it is important to manage wetland and grassland habitats as multiple habitat patches in a variety of successional stages to insure that some habitat patches will always be in the late seral stages favored by harriers. The time needed between disturbance events is much shorter on the lusher, more productive tallgrass prairies than in mixed-and shortgrass habitats.

While federal protection and appropriate management of wetland and grassland habitats on public lands is a critical step towards improving habitat conditions for many bird species, conservation actions on private land deserve increased attention. This is of particular importance in the Great Plains, where more than 70 percent of the land is privately owned. Conservation programs aimed at wetlands and prairie lands important to birds and that develop and strengthen partnerships between landowners and state and federal managers would benefit northern harriers and other wildlife species. Undoubtedly, there must be a more conservative use of resources in the agricultural community (Bragg and Steuter 1996). This is likely to be accomplished only through incentive-based programs for landowners to conduct agricultural practices in a manner beneficial to wildlife or to create and restore degraded wildlife habitats.

Two such incentive programs, administered by the USDA Natural Resource Conservation Service, are the Conservation Reserve Program (CRP) and Wetland Reserve Program. Both programs provide technical and financial assistance to eligible landowners, farmers, and ranchers to address natural resource concerns on their lands, including the protection, creation, or restoration of wildlife habitat, in an environmentally beneficial and cost-effective manner. The largest enrollment of grassland CRP acreage is in southwestern Kansas (Busby and Zimmerman 2001). A high abundance of northern harriers reported in this area suggests that the CRP may be benefiting this species. However, there is not a standardized monitoring program to measure the effectiveness of either of these programs for wildlife, and this represents an important data gap in determining the extent to which these programs improve habitat for wildlife, including the northern harrier.

Another example of a program attempting to create multi-stakeholder partnerships interested in grassland conservation is the Rocky Mountain Bird Observatory's (RMBO) large-scale grassland conservation plan "Prairie Partners: Conserving Great Plains Birds and Their Habitats." RMBO's focus is on encouraging the cooperation of private organizations and government agencies responsible for managing areas and programs important for birds. They accomplish this goal by:

- working with interested landowners and other federal, state, and private partners to design projects to enhance bird habitat on private lands
- providing technical assistance to landowners and land managers on how to incorporate birds into their management strategies

- ❖ conducting outreach to increase awareness and understanding of prairie birds and their habitat requirement

- ❖ monitoring prairie birds and their habitats.

There is no information on the effectiveness of this program.

Tools and practices

Species inventory and monitoring

An efficient, yet rigorous sampling program to census and detect trends for northern harrier populations is lacking, and this hampers the construction of a conservation strategy for the northern harrier. Northern harriers are poorly sampled by BBS and other standard avian surveys because they occur sparsely, have large home ranges, and nest inconspicuously under dense vegetative cover, often in wet or flood prone areas that are not easily accessible to surveyors.

However, because harriers are diurnal raptors and favor open habitats, there are at least two alternatives for developing an inventory or monitoring program during either the breeding or nonbreeding season. First, roadside surveys have proven to be an effective tool for monitoring local harrier populations and other large raptor species. The northern harrier population was monitored effectively by roadside surveys on Nantucket Island, Massachusetts (Combs-Beattie 1993). Road surveys are usually conducted in rural areas from automobiles traveling at 10 to 25 miles per hour. During such surveys, a non-driving observer searches for, and records, all raptors sighted within a quarter-mile of either side of the road. Survey routes can range from 30 to 60 miles in length. Raptors are identified to species whenever possible, and their behavior (perched, flying, eating, etc.) when first sighted is recorded. If possible, additional information such as habitat characteristics should be recorded. Results are usually summarized as numbers of birds seen per unit of distance traveled. Secondly, because of their propensity to roost communally outside of the breeding season, northern harriers could be surveyed as they disperse from and return to their roosts. Communal roost sites tend to be traditional within regions, and counts at such sites may be effective in monitoring populations over wide areas (Bildstein 1979, Fraser and Coleman 1990).

There are several issues to consider when developing an inventory or monitoring program for northern harriers. Harriers often occupy the same nest sites or nesting territories in successive years. Therefore, previously used nesting sites should be checked at least every other year for signs of breeding activity (MacWhirter and Bildstein 1996). Northern harrier mating systems may be polygynous, and therefore the total number of observed nests or females may be a better indicator of breeding density than the number of observed breeding pairs. Finally, because northern harrier populations are closely associated with small mammal populations, a decrease in the number of nesting birds may be the result of a low vole year instead of signifying a serious population decline (NatureServe Explorer 2004).

An additional strategy for monitoring population trends is through regional networks of migration count stations. This method has proven to be effective for many migrating raptors, including the northern harrier (Hoffman and Smith 2003). Numerous migration count stations are located in eastern and western North America, but such stations are relatively absent in the area encompassed by Region 2. Monitoring sites are chosen along major migration corridors or bottlenecks in easily accessible locations that provide good visibility, such as mountain ridges and passes, river valleys, or lake shores. HawkWatch International is working towards a more uniform distribution of fall monitoring sites across the three major western flyways (Pacific, Intermountain, and Rocky Mountain). Individuals in Region 2 interested in developing a migration count station may want to consider consulting HawkWatch International (http://hawkwatch.org) or Hawk Mountain Sanctuary (http://www.hawkmountain.org).

Although population monitoring provides population trend information, demographic studies on productivity, survivorship, and recruitment are necessary to understand the underlying causes of population change (Butcher et al. 1992). Demographic data enables biologists to construct models relating reproduction and survival to habitat, management actions, and other ecological factors (e.g., weather). These models, in turn, can be used to evaluate the effectiveness of management actions, identify management priorities, or assess population viability. Habitat- and landscape-specific vital rates also provide a clear index of habitat and landscape quality (Fancy and Sauer 2000). Thus, we suggest an integrated approach of population trend and demographic monitoring for northern harriers to detect population trends and determine causes of population changes, and to identify and test management strategies that will benefit northern harriers (Marzluff et al. 2000).

Habitat inventory and monitoring

Habitat inventory and monitoring should be conducted concomitant to northern harrier monitoring and demographic studies. Identifying relationships between habitat characteristics and northern harrier abundance, trends, and vital rates is critical for determining causes of population changes and for identifying, as well as assessing, consequences of management activities and conservation strategies (Fancy and Sauer 2000). Hutto and Young (1999) found that within only a few years, and long before they ever calculated a species population trend, habitat data revealed potential issues of management concern for many species.

Vegetation should be characterized at multiple spatial scales, including the site-, patch-, and landscape-level. Site- and patch vegetation variables measured should include structural characteristics of the vegetation at different layers as well as tree and shrub species composition; characteristics that may be important to northern harriers are described previously in the Habitat Section. Specific techniques for sampling avian habitats and analysis can be found in Young and Hutto (2002) and BBIRD protocols (a national program for monitoring breeding productivity and habitat conditions for nongame birds using standardized sampling protocols; Martin et al. 1997). GIS techniques should be used to identify landscape-level characteristics related to northern harrier distribution and abundance, such as patch size, and proximity to human and agricultural development.

Management approaches

Within Region 2, few management recommendations have been developed specifically for northern harriers, and information on the effectiveness of specific habitat management approaches in creating habitat or influencing long-term population viability is lacking. Dechant et al. (2003) provide recommendation for this species at a range-wide scale, focusing on grassland ecosystems. Most recommendations are based on information gained from studies investigating the relationship between northern harrier presence and abundance and habitat management. Unfortunately, there is a lack of data on the demographic consequences of habitat choice by northern harriers illuminating a significant information need. Of the five states within Region 2, Colorado and Wyoming have completed bird conservation plans (Colorado Partners in Flight 2000, Nicholoff 2003). Both provide management recommendations for northern harriers, as well as other priority bird species, in wetland and grassland habitats. The harrier is identified as a priority species in both plans for wetland habitats, and as such most management and conservation recommendations are related to wetland habitats. Because habitat loss has been such an important factor in the decline of this species, conservation programs aimed at restoring habitat and improving habitat quality, such as the CRP and Wetland Reserve Program, are strongly encouraged.

The following section summarizes the primary management approaches, relevant to Region 2, reported in PIF state bird conservation plans (Colorado Partners in Flight 2000, Nicholoff 2003) and other scientific reports (Dechant et al. 2003) to achieve the desired conditions in wetland and grassland ecosystems that benefit northern harrier populations and their prey. Many are similar to management recommendations made by Serrentino (1992) for northern harriers in the northeastern United States.

1. Protect, create, and maintain large areas (greater than 100 ha) of grassland and wetland habitats with tall dense grasses and emergent vegetation in areas where northern harriers occur.

2. Maintain a mosaic of grassland and wetland habitats in different successional stages so that northern harriers have options for establishing breeding grounds in any given year.

3. Use conservation easements, land purchases, and private landowner habitat incentive to develop conservation partnerships between landowners, land managers, and private organizations to protect habitat and create habitat. Management schemes for both waterfowl and upland game birds will generally benefit harriers.

4. Increase the amount of rangeland where livestock are excluded, particularly on USFS national grasslands.

5. Maintain stable water levels in wetlands. Do not allow water levels to rise above 15 cm during the nesting period (April to August) to minimize the risk of nests becoming flooded.

6. Avoid management treatments (e.g., grazing, mowing, burning) in nesting habitat during the breeding season, as they cause nest abandonment and destruction, and increase the incidence nest predation.

7. In tallgrass prairie, grazing, burning, and mowing every three to five years is effective in reducing woody succession and removing over-accumulation of plant litter; subsequent regrowth creates favorable conditions for nesting harriers and their principal small rodent prey.

8. Avoid or minimize pesticide use in areas where northern harriers occur, as pesticide ingestion has been implicated in the long-term decline of harrier populations.

Information Needs

Information on age-specific fecundity, survivorship, and dispersal for the northern harrier is lacking and represents a significant research need. Without these demographic data, it is difficult to understand and to predict the effects of different management options and conservation actions on population trends, population persistence, and source-sink dynamics (Herkert and Knopf 1998). Because northern harrier breeding and nonbreeding densities are known to vary with respect to suitability of available habitat, prey abundance, availability of nest sites, and frequency of polygyny (Craighead and Craighead 1956, Picozzi 1978, Balfour and Cadbury 1979, Hamerstrom et al. 1985), it is important to make region-specific assessments of the amount and type of habitats required to maintain viable populations at breeding sites, wintering grounds, and communal roosts. Considering that northern harriers utilize young conifer plantations and second-growth forest as breeding habitat in other regions of the United States, studies to determine if harriers use these habitat in Region 2 are also needed.

Although management recommendations proposed by Colorado and Wyoming Partners in Flight bird conservation plans (Nicholoff 2003) and Dechant et al. (2003) suggest conservation actions at a relatively large scale (i.e., >100 ha tracts of contiguous wetland and grasslands), based on this species' apparent sensitivity to area, few studies provide supporting demographic evidence. This association is due, in part, to this species' large home ranges and their apparent nomadic behavior. However, studies that improve our knowledge of how landscape context influences northern harrier's sensitivity to habitat fragmentation would provide important information that can guide conservation planners in determining how large wetland and grassland conservation areas should be, how they should be spatially arranged, and into what type of landscapes they should be placed (Herkert and Knopf 1998).

Studies investigating migration patterns could provide a fruitful course of research, as timing and routes of migration are currently not well quantified (MacWhirter and Bildstein 1996). A more precise knowledge of migration routes and stopover sites would provide much needed information for tracking and surveying populations. At least two organizations, HawkWatch International and Hawk Migration Association of North America, are working to expand their existing network of migration survey locations, and better information on migration routes would improve the ability of these organizations to identify those sites where the best data can be gathered. Certainly, developing and implementing a more accurate and reliable regional and national survey method is needed to reliably assess the species' status within Region 2 and other areas across the species' range.

Much information remains to be learned about this species' use of communal roosts on wintering grounds. Monitoring populations at roost sites could provide knowledge of the distribution of sexes on wintering grounds and the stability of populations during the nonbreeding season (MacWhirter and Bildstein 1996). In addition, the effect of roost site availability on population density remains largely unstudied. Food regurgitations can be easily collected from communal roosts, and therefore, these sites may also serve as useful areas for studying northern harrier diet.

Long-term studies that monitor harrier response to different management frequencies, intensities, and combination of management practices are needed and would be especially helpful in the conservation of this species. At a minimum, both fire and grazing management applications need to be considered; investigation of other agricultural activities such as haying would also be useful. Given the degree to which these activities occur in the Great Plains, public lands of Region 2 would appear to offer the most promising locations for such studies. Research designs should be implemented, using an adaptive management approach to allow for refinement in management decisions and additional research questions (Herkert and Knopf 1998).

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